



CISCO NETWORKING ACADEMY PROGRAM



CCNA 1:

Networking Basics v3.1

Instructor Guide

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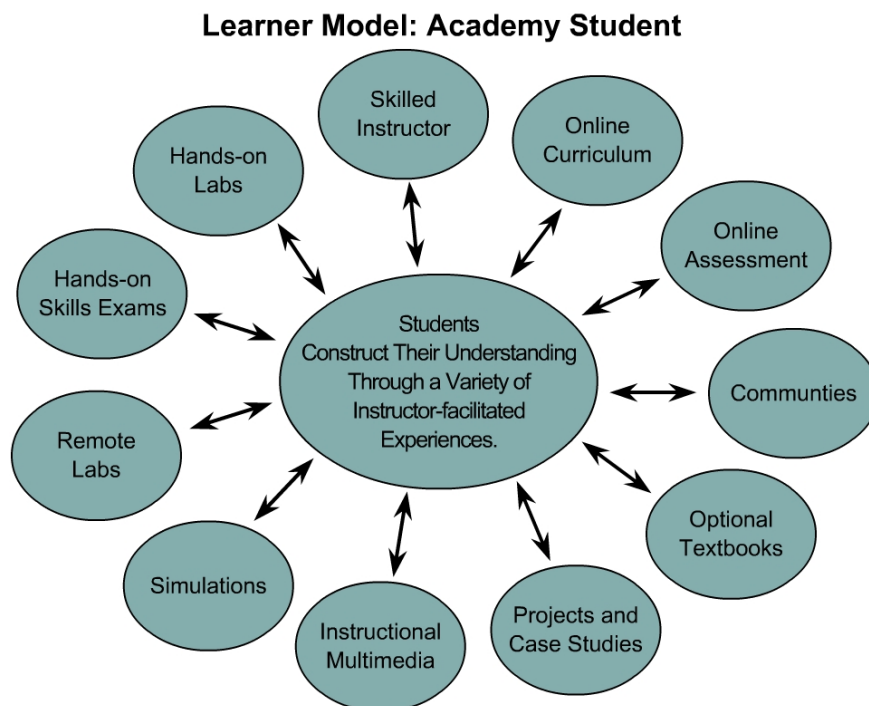


I. Welcome

Welcome to the CCNA 1 version 3.1 Instructor Guide. This guide is designed to make teaching the CCNA 1 course a little easier. As an introduction to this guide, four themes will be emphasized.

Student-centered, instructor-facilitated

The CCNA curriculum has not been designed as a stand-alone e-learning or a distance-learning course. The Cisco Networking Academy Program is based on instructor facilitation. The diagram "Learner Model: Academy Student" summarizes the emphasis that Cisco Worldwide Education (WWE) puts on the student. The instructor utilizes activities, built from a variety of resources, to help the students achieve desired understandings of networking.



One curriculum does not accommodate all students

The Cisco Networking Academy Program is used by hundreds of thousands of students in almost 150 countries. Students vary from teenagers to mature adults, at different levels of education.

One curriculum cannot be perfect for all students. The local instructors utilize the learning goals of the program, and the resources described in the learner model to make the program work for their specific students. Instructors are given the following reference points to plan their instruction:

- Mission of WWE to educate and train
- Requirements of the CCNA certification exam
- Hands-on skills that help make students ready for industry and further education

The policy of WWE is to support additions to the curriculum, but not the removal of any of the curriculum. In-class differentiation is encouraged. Here, struggling students are given remediation and high-achieving students are given further challenges.

The instructor decides how much time to spend on various topics. Depending on the students, some topics can be emphasized and other topics can be covered with less emphasis. Only the local instructor can decide how to balance the need to do hands-on labs with the realities of the local student-to-equipment ratio and time schedule. Using this guide may facilitate preparation of lesson plans and presentations. Instructors are strongly encouraged to research and use external sources and develop in-house labs and exercises.

To assist the instructor in course and lesson planning, certain Target Indicators (TIs) have been emphasized for particular importance. However, these TIs are not the only ones that need to be taught. Often an emphasized TI will only make sense if preceding TIs are understood. It may be useful to have a diagram of the TIs that best emphasize the knowledge and skills that are needed for success in the CCNA program.

Assessment is multifaceted and flexible. A wide variety of assessment options exist to provide feedback to the students and document their progress. The Academy assessment model is a blend of formative and summative assessments that include online and hands-on skills-based exams.

Hands-on, skills-based

The core of the CCNA 1 experience is a sequence of hands-on labs. Each lab has been designated as either core or optional. Essential Labs must be completed. They are fundamental to the CCNA Academy student experience, certification test requirements, job success, and cognitive and affective development. In CCNA 1, students must master interconnecting PCs, hubs, switches, routers, Ethernet cables, and serial cables to have Layer 1 connectivity across a network.

The Cisco community

Cisco instructors are members of a global community of educators. More than 10,000 individuals are actively teaching the CCNA and CCNP courses. Instructors are encouraged to take advantage of this community through their Regional Academies (RAs), Cisco Academy Training Center (CATC), the Cisco Academy Connection, and through other forums. It is the commitment of WWE to improve the curriculum, assessment, and instructional resources. Feedback can be submitted through the Cisco Academy Connection. Please continue to check the Cisco Academy Connection for regular releases of instructional materials.

Guide overview

Section II, “Course Overview”, provides a scope and sequence type overview of the course. Section III, “Guide to Teaching TI by TI”, summarizes the most important learning objectives, target indicators, and labs. This section also offers teaching suggestions and background information. Section IV, “Case Study”, provides an overview to the Structured Cabling Case Study and Wiring Project. Section V, “Appendixes”, includes “Cisco Online Tools and Utilities”, “CCNA Assessment Guidelines”, “Evidence Centered Design of Assessment Tasks in the Networking Academy”, and “Instructional Best Practices”.

Three additional materials that come with this guide to provide help with teaching the CCNA 1 course:

- **Instructor Lab Manual** — this document contains instructor versions of labs, including lab solutions.
- **Student Lab Manual** — this document contains student versions of labs.

- **Skills-Based Assessment** — this document provides examples of what is expected as a final performance-based assessment for the CCNA 1 course.

II. Course Overview

Target Audience

The target audience is anyone who desires a practical, technical introduction to the field of networking. This includes students of all levels who are interested in careers as network technicians, network engineers, network administrators, and network help-desk staff.

Prerequisites

The successful completion of this course requires the following:

- Reading level of 13-years-old or higher
- Basic computer literacy and awareness of the Internet

The following skills are beneficial, but not required:

- Prior experience with computer hardware, binary math, and basic electronics
- Background in cabling

Course Description

CCNA 1: Networking Basics is the first of four courses leading to the Cisco Certified Network Associate (CCNA) designation. CCNA 1 introduces Cisco Networking Academy Program students to the networking field. The course focuses on the following:

- Network terminology
- Network protocols
- Local-area networks (LANs)
- Wide-area networks (WANs)
- Open System Interconnection (OSI) model
- Cabling
- Cabling tools
- Routers
- Router programming
- Ethernet
- Internet Protocol (IP) addressing
- Network standards

In addition, the course provides instruction and training in the proper care, maintenance, and use of networking software, tools, and equipment.

Course Objectives

The CCNA certification indicates knowledge of networking for the small office, home office (SOHO) market. The certification also indicates the ability to work in small businesses or organizations using networks that have fewer than 100 nodes.

A qualified CCNA should be able to perform the following tasks:

- Install and configure Cisco switches and routers in multiprotocol internetworks using LAN and WAN interfaces
- Provide Level 1 troubleshooting service
- Improve network performance and security
- Perform entry-level tasks in the planning, design, installation, operation, and troubleshooting of Ethernet and TCP/IP networks

The CCNA 1 course is an important step toward achieving CCNA certification.

Upon completion of this course, students will be able to perform tasks related to the following:

- Networking mathematics, terminology, and models
- Networking media such as copper, optical, and wireless
- LAN and WAN testing and cabling
- Ethernet operation and 10, 100, or 1000-Gb versions of Ethernet
- Ethernet switching
- IP addressing and subnetting
- IP, TCP, UDP, and application layer protocols

Lab Requirements

Please refer to the latest CCNA equipment bundle spreadsheets on the Academy Connection site.

Certification Alignment

The curriculum is aligned with the following Cisco Internet Learning Solution Group (ILSG) courses:

- CCNA (Cisco Certified Network Associate)
- INTRO (Introduction to Cisco Networking Technologies)

CCNA 1 Course-Level Claims

A competent student will be able to perform the following tasks:

- Describe and install the hardware and software required to be able to communicate across a network.
- Demonstrate the mathematical skills required to work with decimal, binary, and hexadecimal numbers.
- Define and describe the structure and technologies of computer networks.
- Describe the meaning and application of bandwidth when used in networking.
- Describe, compare, and contrast network communications using two examples of layered models.
- Describe the physical, electrical, and mechanical properties and standards associated with copper media used in networks.
- Describe the physical, electrical, and mechanical properties and standards associated with optical media used in networks.

- Describe the standards and properties associated with the transmission and reception of wireless signals used in networks.
- Describe what is required to install a simple WLAN.
- Explain the issues associated with the transmission of signals on networking media.
- Describe the topologies and physical issues associated with cabling common LANs.
- Describe the physical issues associated with cabling networking equipment to work over a WAN link.
- Explain the fundamental concepts associated with the Ethernet media access technique.
- Explain how collisions are detected, and the concepts associated with auto-negotiation on an Ethernet system.
- Describe the principles and practice of switching on an Ethernet network.
- Compare and contrast collision and broadcast domains, and describe the process of network segmentation.
- Explain and demonstrate the mechanics associated with IP addressing.
- Describe how an IP address is associated with a device interface, and the association between physical and logical addressing.
- Explain and demonstrate the mechanics associated with IP subnetting.
- Describe the principles and practice of packet switching utilizing IP.
- Describe the concepts associated with routing and the different methods and protocols used to achieve it.
- Describe how the protocols associated with TCP/IP allow host communication to occur.
- Describe the fundamental concepts associated with transport layer protocols and compare connectionless and connection-oriented transport methods.
- List the major TCP/IP application protocols, and briefly define their features and operation.

Course Overview

The course has been designed for 70 contact hours. Approximately 35 hours will be designated to lab activities and 35 hours will be spent on curriculum content. A case study on structured cabling is required, but format and timing will be determined by the Local Academy.

The following changes have taken place since CCNA version 2.x:

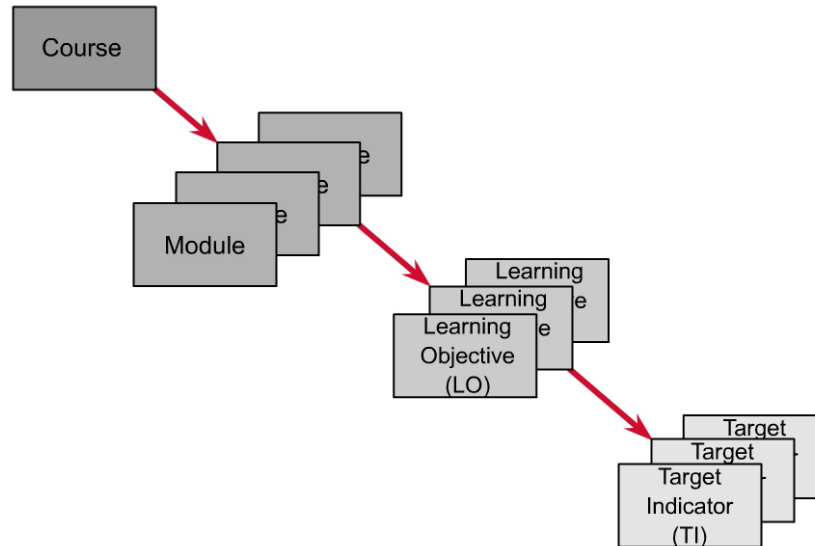
- More information on optical and wireless media
- More cable testing terminology and concepts
- More details on the operation of Ethernet
- More focus on Fast, Gigabit, and 10-Gigabit Ethernet
- Structured cabling resource materials have been moved to the case study
- The case study is now required with format and timing determined by the Local Academy.
- More interactive flash activities

- Lab focus on cable making, building small networks, and interconnecting devices

III. Guide to Teaching TI by TI

Nomenclature

The CCNA curriculum uses the following hierarchy:



For example, 3.2.5 would be read as Module 3, learning objective (LO) 2, target indicator (TI) 5. However, throughout WWE and Cisco documentation, a variety of terminology is used.

The following terms are commonly used to describe curriculum, instructional materials, and assessment:

- **Certification-level claims**

Certification-level claims are high-level statements in regards to the knowledge a CCNA-certified person should have. These statements ultimately govern the certification exams. Claims are supported with data and used in the assessment process as a measure of performance.

- **Course**

A course is a subset of a curriculum. A scheduled course is taught as a collection of chapters.

- **Course-level claims**

Course-level claims are medium-level statements about what a person who completes the CCNA 1 course should know. Claims are supported with data and used in the assessment process as a measure of performance.

- **Core TI**

A core TI applies directly to the claims and LOs. Do not omit a core TI when teaching the course.

- **Curriculum**

A curriculum is a predefined or dynamic path of learning events. A curriculum has an end goal such as certification or achieving required job skills and knowledge.

- **Hands-on skill**

The hands-on skills and the certification and course level claims cover some of the same subjects. These skills are explicitly listed to emphasize hands-on lab-based learning.

- **Module**

A module is a logical grouping that comprises a course. Modules consist of multiple LOs that are similar to chapters.

- **Learning objective (LO)**

An LO is a statement that establishes a measurable behavioral outcome. The outcome is used as an advanced organizer to show how the increase of skills and knowledge is being measured. An LO is similar to a reusable learning object (RLO).

- **Lesson**

A lesson is a presentation of a coherent set of TIs to meet an LO. The term lesson emphasizes the role of the instructor. The term LO emphasizes the role of the student.

- **Module caution**

A module caution is a suggestion on where difficulties may be encountered. These suggestions are especially important for syllabus development, lesson planning, and pacing.

- **Optional lab**

An optional lab is an activity for practice, enrichment, or differentiation.

- **Essential lab**

A lab that is fundamental to the course.

- **Reusable learning object (RLO)**

An RLO is a Cisco instructional design term. It is a collection of reusable information objects (RIOs) that supports a specific LO.

- **Reusable information object (RIO)**

A RIO is a Cisco instructional design term. It is a collection of content, practice, and assessment items assembled around a single learning objective. A RIO is similar to a TI.

- **Target indicator (TI)**

A TI is typically one text frame with graphics and several media content items in the form of text, graphics, animation, video, or audio.

Module 1: Introduction to Networking

Overview

Course business will need attention when teaching Module 1. The time required to cover this module may vary considerably with different student populations.

Module 1 Caution:

Mathematics may cause difficulties for many students. The diversity of prior experiences of the students may be great.

Students completing this module should be able to perform tasks related to the following:

- Understand the physical connection that has to take place for a computer to connect to the Internet
- Recognize the components that comprise the computer
- Install and troubleshoot network interface cards and modems
- Use basic testing procedures to test the Internet connection
- Demonstrate a basic understanding of the use of Web browsers and plug-ins
- Recognize the Base 10, Base 2, and Base 16 number systems
- Perform 8-bit binary to decimal and decimal to 8-bit binary conversions
- Perform simple conversions between decimal, binary, and hexadecimal numbers
- Recognize the binary representation of IP addresses and network masks
- Recognize the decimal representation of IP addresses and network masks

1.1 Connecting to the Internet

Essential Labs: 1.1.6, 1.1.7, and 1.1.9

Optional labs: 1.1.2 and 1.1.8

Core TIs: All

Optional TIs: none

Certification-level claim: none

Course-level claim: Students completing this module should be able to perform basic tasks related to networking.

Hands-on skills: Install the hardware and software required to be able to communicate across a network.

1.1.1 Requirements for Internet connection

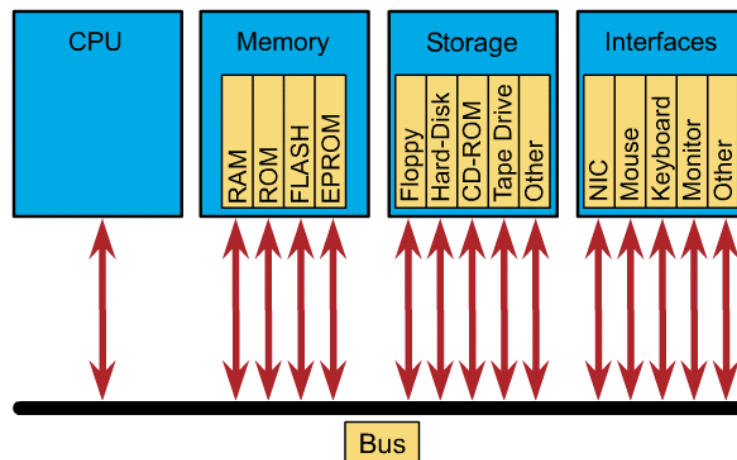
It is important for students to understand the structure of the Internet. Students will be familiar with the services that the Internet provides. However, they generally do not understand the complexity of the Internet. Emphasize that terms such as TCP/IP and Ethernet will become very familiar to them.

Motivate the students by utilizing the website *An Atlas of Cyberspaces: Mapping Cyberspace Using Geographic Metaphors* at <http://www.cybergeography.org/atlas/geographic.html>. This site has a wide variety of insightful and fascinating visualizations and maps of the Internet. When utilities such as *tracert* and programs such as *Neotrace* are demonstrated, students tend to ask questions about networking. This can set a tone of inquiry for the rest of the course. Ask the students to keep a journal. An early journal entry might be to respond to the questions “what happens when enter is pressed”, “how does a web page request result in a web page from across the world”, or “how does e-mail get here?”.

1.1.2 PC basics

The elemental components of computers are discussed in this TI. It is beneficial to pass around components such as motherboards, network interface cards (NICs), drives, and old circuit boards to students. The lab “PC Hardware” should be considered optional but is important for students new to IT. The graphic allows for the comparison of the insides of the PC and computer networks.

An Idealized Computer: Information Flow



1.1.3 Network interface card

Students should understand the function of a NIC and be able to test the NIC by inserting it into a motherboard. It is not important, at this stage, that this be a working computer. The components mentioned previously can be used. The IT department is a good source for old parts that may be used for this exercise. Ethernet NICs are increasingly being integrated onto motherboards. The NIC is simply called an interface on switches and routers.

1.1.4 NIC and modem installation

Dial-up analog modems have many known limitations. However, they remain a primary means of accessing the Internet worldwide. Earlier versions of the curriculum had a lab for NIC installation and some academies may still want to perform it.

1.1.5 Overview of high-speed and dial-up connectivity

Take a survey of the class to find out the type of home connectivity they may have. This connectivity could be cable modem, DSL, dial-up modem, or none. Discuss the differences in speeds. Discuss that CCNA 4 will deal with these issues in greater depth.

1.1.6 TCP/IP description and configuration

The lab "PC Network TCP/IP configuration" is required. All students will need this skill repeatedly through the four semesters.

1.1.7 Testing connectivity with ping

Have the students use the `ipconfig` or `winipcfg` command from the DOS command prompt to discover the host and gateway addresses. The lab "Using ping and tracert from a Workstation" is required. All students will need this skill repeatedly through the four semesters. Emphasize to the students that tracert is built out of pings.

1.1.8 Web browser and plug-ins

Discuss the differences between IE and Netscape. Remind students that all sites do not accept all browsers. There are other browsers available and students could be assigned to research and report back on the other browsers. It is crucial to the success of the students, and the ease with which they will work with the curriculum, that they understand how to access the Internet. This is also a good time to verify that all students have login and password access to the curriculum student site. The lab "Web Browser Basics" is considered optional, though beginning students may need to master this knowledge.

1.1.9 Troubleshooting Internet connection problems

Use the graphic in this TI and reinforce the troubleshooting process. There are many different approaches to troubleshooting. Other alternative approaches may be added. The lab is required, though instructors are encouraged to modify it to the lab environment and the students. The most common activity of a qualified CCNA individual in industry surveys is troubleshooting. This troubleshooting begins with the simple desktop support-type issues.

1.2 Network Math

Essential Labs: none

Optional labs: 1.2.5, 1.2.6, and 1.2.8

Core TIs: All

Optional TIs: none

Course-level claim: Demonstrate the mathematical skills required to work effortlessly with integer decimal, binary, and hexadecimal numbers and simple binary logic.

Hands-on skills: none

1.2.1 Binary presentation of data

The ASCII converter is included in this TI to underscore that familiar letters and numbers can be represented in binary. One activity is to assign a couple of characters to each student. The binary code is then reported to the class. Students may be interested in the range of information that can be represented in binary. ASCII is a good example of text. Using a program like Paint, pixels can be shown. Suggest how rows and columns could be given coordinate numbers in binary. In each pixel, a 1 or 0 bit can represent a part of a black and white picture. The students should be asked how color might be represented. Video can be introduced as a succession of these binary-encoded still images. Additional binary code to represent the time sequences can also be introduced. Sound waves can be represented in binary after analog to digital conversion.

For the historically or mathematically inclined, search for the story of Claude Shannon's classic paper "A Mathematical Theory of Communication" (Bell System Technical Journal 1948).
<http://cm.bell-labs.com/cm/ms/what/shannonday/paper.html> This paper revolutionized telecommunications and facilitated the way for modern Information Science.

1.2.2 Bits and bytes

Students should understand the units of bits and bytes, the abbreviations, and the representation of binary 1s and 0s in voltage terms. For optical systems, bits can be signaled by light pulses, bright/dim, or on/off. For wireless systems, radio waves with changing amplitude, frequency, or phase can signal bits. Most often it is the phase that signals the bits. Have students do some simple conversions. Start anticipating the common misconceptions about bits, bytes, and bits per second.

Practice problems

The Voyager spacecraft, launched in 1977, can send data back at the rate of 44800 bits per second and can store up to 500 million bits of data on the on-board digital tape.

What is the actual number of bytes and kilobytes the Voyager can send per second?

$44800 \text{ bits} \div 8 = 5600 \text{ bytes per second}$

$44800 \text{ bits} \div 1024 = 43.75 \text{ kilobytes per second}$

How many megabytes of data can be stored on the digital tape?

$500,000,000 \text{ bits} \div 1,048,576 = 476.84 \text{ megabytes}$

Each Voyager spacecraft also contains six processors, which can handle 540864 bits of data capacity.

How many kilobytes of data can the Voyager processors handle?

$540864 \text{ bits} \div 1024 = 528.1875 \text{ kilobytes (0.5 megabyte)}$

A school district network area storage system can store 40 terabytes of student and teacher files.

How many bytes of data is the system capable of storing?

$40 \times 1,099,511,627,778 = 43,980,465,111,120 \text{ bytes (or } 351,843,720,888,960 \text{ bits; } 40,960 \text{ gigabytes)}$

<http://ringmaster.arc.nasa.gov/voyager/hardware/intro.html>

<http://voyager.jpl.nasa.gov/faq.html>

1.2.3 Base 10 number system

This TI discusses the decimal, Base 10, numbering system. Knowing how the decimal system works is important because it is needed to understand the binary, Base 2, and hexadecimal, Base 16, numbering systems. This TI may be more crucial for some students than others. Powers of 10 are important part in understanding units of information, units of bandwidth, physical dimensions of networks, and cable testing measurements. These topics are all related to the CCNA program.

Practice problem

Write the following Base 10 numbers using the 10^x notation for each place value:

1. 873 $(8 \times 10^2) + (7 \times 10^1) + (3 \times 10^0)$
2. 3,746 $(3 \times 10^3) + (7 \times 10^2) + (4 \times 10^1) + (6 \times 10^0)$
3. 4,056 $(4 \times 10^3) + (0 \times 10^2) + (5 \times 10^1) + (6 \times 10^0)$
4. 65,802 $(6 \times 10^4) + (5 \times 10^3) + (8 \times 10^2) + (0 \times 10^1) + (2 \times 10^0)$
5. 9,869,124 $(9 \times 10^6) + (8 \times 10^5) + (6 \times 10^4) + (9 \times 10^3) + (1 \times 10^2) + (2 \times 10^1) + (4 \times 10^0)$

1.2.4 Base 2 number system

It is extremely important to prepare the student for the use of binary math. Using the curriculum graphic, discuss the position of the eight bits in an octet. Consider introducing an IP address with all four octets at this time. Be sure that the students understand the place values. Have students commit the place values in an 8-bit binary number to memory. Most binary calculations can be derived from these place values. Students must be skilled with hand calculations involving binary numbers in preparation for the CCNA certification exam. Also, students will struggle with binary math throughout the course if they have not acquired the necessary skills.

Practice problem

Write the following Base 2 numbers using the 2^x notation for each place value:

1. 10011011 $(1 \times 2^7) + (0 \times 2^6) + (0 \times 2^5) + (1 \times 2^4) + (1 \times 2^3) + (0 \times 2^2) + (1 \times 2^1) + (1 \times 2^0)$
2. 11011100 $(1 \times 2^7) + (1 \times 2^6) + (0 \times 2^5) + (1 \times 2^4) + (1 \times 2^3) + (1 \times 2^2) + (0 \times 2^1) + (0 \times 2^0)$
3. 01011110 $(0 \times 2^7) + (1 \times 2^6) + (0 \times 2^5) + (1 \times 2^4) + (1 \times 2^3) + (1 \times 2^2) + (1 \times 2^1) + (0 \times 2^0)$
4. 01010111 $(0 \times 2^7) + (1 \times 2^6) + (0 \times 2^5) + (1 \times 2^4) + (0 \times 2^3) + (1 \times 2^2) + (1 \times 2^1) + (1 \times 2^0)$
5. 11101110 $(1 \times 2^7) + (1 \times 2^6) + (1 \times 2^5) + (0 \times 2^4) + (1 \times 2^3) + (1 \times 2^2) + (1 \times 2^1) + (0 \times 2^0)$

1.2.5 Converting decimal numbers to 8-bit binary numbers

Perform this exercise for the students a few times using Figure 1. Now put a number at the top of the chart and have a student perform the calculation. As each student finishes they may change the number and select the next student. Have the students also practice with the number generators in Figure 2. The lab "Decimal to Binary Conversion" is optional. It does not need to be done in class, but it could be used as a homework assignment. Consider an activity called "kinesthetic binary". Here eight students represent bits in specific place values. The students stand up for binary 1 or sit down for binary 0 in response to a decimal number called out by the instructor.

Practice problem

Using the flowchart on 1.2.5, convert the following decimal numbers into binary:

1. 216 11011000 ($216 = 128 + 64 + 16 + 8$)
2. 119 01110111 ($119 = 64 + 32 + 16 + 4 + 2 + 1$)
3. 41 00101001 ($41 = 32 + 8 + 1$)
4. 255 11111111 ($255 = 128 + 64 + 32 + 16 + 8 + 4 + 2 + 1$)
5. 188 10111100 ($188 = 128 + 32 + 16 + 8 + 4$)

1.2.6 Converting 8-bit binary numbers to decimal numbers

The lab "Binary to Decimal Conversion" is optional. It does not need to be done in class, but it could be used as a homework assignment.

Practice problem

Using the flowchart on 1.2.6, or by using the same technique as in 1.2.4, convert the following binary numbers into decimal:

1. 01101011 107
2. 10010110 150
3. 11101001 233
4. 00011011 27
5. 01111111 127

1.2.7 Four-octet dotted decimal representation of 32-bit binary numbers

This TI introduces the binary representation of four-octet dotted decimal numbers. This concept may prove to be overwhelming for some students. Assure the students this representation is used consistently in networking. Build on the knowledge from TI 1.2.4 by re-emphasizing place values.

Practice problem

Convert the following IP addresses into binary. Do not forget to put the period, or dot, between each group of eight binary digits:

1. 192.168.87.121 11000000.10101000.01010111.01111001
2. 64.133.9.250 01000000.10000101.00001001.11111010
3. 157.90.146.18 10011101.01011010.10010010.00010010
4. 210.17.81.130 11010010.00010001.01010001.10000010
5. 190.200.73.10 10111110.11001000.01001001.00001010

1.2.8 Hexadecimal

Students should understand the process of converting numbers 255 and lower to hexadecimal. Experimentation may be done with larger numbers, as time permits. Indicate to the students that in Modules 6 and 7, hex is important for understanding LAN addresses. IP v6 will be written in hex. The lab, "Hexadecimal Conversion", can be considered optional. It does not need to be done in class, but could be used as a homework assignment.

Practice problems

Convert the following binary numbers into hexadecimal. Remember to break up the binary numbers into groups of four digits:

1. 1100000010101000 1100 0000 1010 1000 0xC0A8
2. 0001000101010001 0001 0001 0101 0001 0x1151
3. 1011111011000100 1011 1110 1100 0100 0xBEC4
4. 0101101010010010 0101 1010 1001 0010 0x5A92
5. 0101011101111001 0101 0111 0111 1001 0x5779

Convert the following hexadecimal numbers into binary. Each hexadecimal digit is converted into four binary digits:

- | | |
|-----------|---------------------|
| 1. 0x2142 | 0010 0001 0100 0010 |
| 2. 0x314B | 0011 0001 0100 1011 |
| 3. 0xBADE | 1011 1010 1101 1110 |
| 4. 0x6C3F | 0110 1100 0011 1111 |
| 5. 0x7D08 | 0111 1101 0000 1000 |

1.2.9 Boolean or binary logic

The area of importance in this TI is the AND process. References are made to the topics of subnetwork and wildcard masking. These functions are explained in depth later in the curriculum. It is suggested that Figure 3 be used as the prime discussion topic because ANDing relates directly to the subnetting exercises later in the curriculum. This information can be related to Boolean web searches. Boolean logic can narrow the search criteria.

Practice problems

Perform the NOT operation on the following binary numbers. To perform the NOT operation, simply reverse the value of each digit:

- | | |
|-------------|----------|
| 1. 10111110 | 01000001 |
| 2. 01001001 | 10110110 |
| 3. 00010010 | 11101101 |
| 4. 10010010 | 01101101 |
| 5. 10101000 | 01010111 |

Both the AND and the OR operations require two separate values to create output. Perform both types of operations on the following pairs of binary numbers:

No.	Problem	Answer	Process
1	10010110 10111001	AND = 10010000 OR = 10111111	AND $\frac{10010110}{10111001}$ OR $\frac{10010110}{10111001}$
2	01011010 10001011	AND = 00001010 OR = 11011011	AND $\frac{01011010}{10001011}$ OR $\frac{01011010}{11011011}$
3	11110010 10011011	AND = 10010000 OR = 11111011	AND $\frac{11110010}{10011011}$ OR $\frac{11110010}{11111011}$
4	10011011 11110000	AND = 10010000 OR = 11111011	AND $\frac{10011011}{11110000}$ OR $\frac{10011011}{11111011}$
5	01111001 11111000	AND = 01111000 OR = 11111001	AND $\frac{01111001}{11111000}$ OR $\frac{01111001}{11111001}$

1.2.10 IP addresses and network masks

This is a good introduction to the subnetting material, but do not let students get confused here. At this TI, lead a discussion and give an overview of IP address and network mask fundamentals. This is not the appropriate time to teach students how to do subnetting. While detailed discussions of the necessity of addressing are in Module 9, many prior labs and concepts in Modules 2 through 8 require IP addresses and subnet masks. To stress the importance of the IP address format point out that the Internet, like the global phone system, needs an addressing scheme.

Module 1 Summary

Before moving on to Module 2, the students must be proficient in decimal to binary conversions, binary representation of multiple forms of data, the units of data storage, and simple troubleshooting tasks involving an Internet connection.

Online assessment options include the end-of-module online quiz in the curriculum and the online Module 1 exam. Lab assessments include informal and formal evaluation of skills such as using ping or tracert, or simple troubleshooting of an Internet connection.

Students should understand the following main points:

- Necessary physical connection for an Internet connection
- Primary computer components
- Installation and troubleshooting of network interface cards and modems
- Basic Internet connection testing procedures
- Web browser selection and configuration
- Base 2 number system
- Binary to decimal number conversion
- Hexadecimal number system
- Binary representation of IP addresses and network masks
- Decimal representation of IP addresses and network masks

Module 2: Networking Fundamentals

Overview

A foundation for future learning will be established if students master the following concepts:

- OSI model
- TCP/IP model
- Units of bandwidth

Module 2 Caution:

The lack of hands-on activities may imply that more active classroom instructional practices may be needed. Students may be completely overwhelmed by vocabulary.

Students completing this module should be able to perform the following tasks:

- Briefly outline the history of networking
- Identify devices used in networking
- Understand the role of protocols in networking
- Define LAN, WAN, MAN, and SAN
- Explain VPNs and their advantages
- Describe the differences between intranets and extranets
- Explain the importance of bandwidth in networking
- Use an analogy from experience to explain bandwidth
- Identify bps, kbps, Mbps, and Gbps as units of bandwidth
- Explain the difference between bandwidth and throughput
- Calculate data transfer rates
- Explain why layered models are used to describe data communication
- Explain the development of the OSI model
- List the advantages of a layered approach
- Identify each of the seven layers of the OSI model
- Identify the four layers of the TCP/IP model
- Describe the similarities and differences between the two models

2.1 Networking Terminology

Essential Labs: none

Optional labs: none

Core TIs: All

Optional TIs: none

Certification-level claim: Describe the components of network devices.

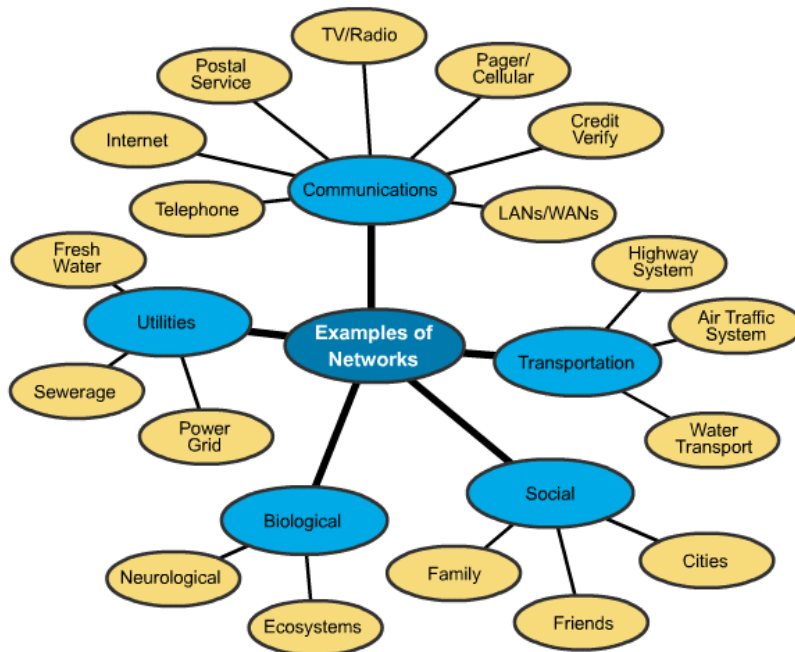
Course-level claim: Define and describe the structure and technologies of computer networks.

Hands-on skills: none

2.1.1 Data networks

All graphics in this TI are animated. Make sure the students understand how to recognize animations and use them. Discussion topics at this TI should include the evolution of LANs, MANs, and WANs. Direct students to Figure 6 "Examples of Data Networks". The film "Powers of 10" by Charles and Ray Eames provides a powerful visual image that can be reinterpreted as physical and geographical scales of network size. Consider leading students through a brainstorming exercise on the meaning of the word "network". The figure shows the results of one such brainstorming.

Networks



2.1.2 Network history

Figure 1 can generate some interesting discussion. Remember that many students have never known a world without computers. Describe ENIAC and the very early computer days to promote their interest. A book about the individuals that were important to the development of the Internet is "Where Wizards Stay Up Late: The Origins of the Internet" by Katie Hafner, 1998, ISBN: 0684832674. Instructors might consider sharing their own history in networking. This shows students the many diverse ways individuals come to the field of networking.

2.1.3 Networking devices

This is a vitally important TI introducing the components of networking. Focus particular attention to Figure 5 as it illustrates the symbols that will be used throughout the curriculum. Have students memorize these and practice drawing them until mastered. PhotoZooms are a good visual aid. However, it is better to use real equipment. Hubs, switches, and routers should be made available. Instruction should focus on allowing the students to associate the name, the symbol, a simple sketch, the physical reality, and finally the functional description of the networking device. Having the student create a chart in their journal could be a valuable resource. Have the students draw the symbols of the devices properly. Topologies are a basic means of communication about networks.

2.1.4 Network topology

The student should understand the differences in topologies and become familiar with the symbols representing each type. Consider having students draw and name the topologies in Figure 1 from memory. Without getting into too much detail, explain that the dots represent stations or nodes with NICs. Ask the students the questions: "What is an advantage of this way of connecting devices?" and "What is a disadvantage?" Consider printing out Figure 2 and have students begin thinking of the devices learned in 2.1.3 and their interconnection. This topology will be revisited in later modules. The teaching topology can be used to generate student questions. For example, a good question would be "What determines where devices are placed?" One thing not explicitly labeled on the diagram is that other than FDDI and Token Ring, the straight lines are Ethernet segments and the lightning bolt is a serial connection. Adding a wireless link to the diagram would make it more relevant to the networks of today.

2.1.5 Network protocols

The definition of protocol suites and their function should be emphasized here. The students should be encouraged to research IEEE, ANSI/EIA/TIA, ISO, and IETF and report back to the class on their findings. This TI is rather abstract. The general knowledge the students have of the word protocol is a good starting point. Then begin to talk about what protocol might mean in the context of data communications. However, since the OSI model has not yet been introduced, the layered diagram will not have much meaning to the students. Either briefly explain the idea of layers or revisit the idea of protocols once the TCP/IP and OSI models have been introduced.

2.1.6 Local-area networks (LANs)

This TI builds on the introductory material in 2.1.1 and illustrates the symbols in Figure 1. Wireless LANs are to be added here where the primary device is the wireless access point and the mobile PC. Remind students about Figure 6 in 2.1.1 where LAN and WAN distances are compared. Ask students to identify what LANs are used. Encourage students to visit <http://www.cisco.com/> for additional information on LANs. Depending on the experience of the students, consider adding a simple definition for VLAN here.

2.1.7 Wide-area networks (WANs)

This TI builds on the introductory material in 2.1.1 and illustrates the symbols in Figure 1. Differentiate between dialup modem and cable modem. Remind students about Figure 6 in 2.1.1 where LAN and WAN distances are compared. Ask students to identify the WAN that is used while at home and at school. Encourage students to visit <http://www.cisco.com/> for additional information on WANs.

2.1.8 Metropolitan-area networks (MANs)

This TI builds on the introductory material in TI 2.1.1 and illustrates the symbols in Figure 1. MANs have the characteristics of both LANs and WANs. Remind students about Figure 6 in TI 2.1.1.

2.1.9 Storage-area networks (SANs)

Little emphasis is given to this topic and it does not reappear in the curriculum. Encourage students to visit <http://www.cisco.com/> for more information. While SANs are a technology that is growing in importance, they are mentioned here just for purposes of awareness.

2.1.10 Virtual private network (VPN)

As telecommuting continues to increase VPNs are becoming more prevalent. Ask students to discover if they have a friend or relative that telecommutes and whether a VPN is used.

2.1.11 Benefits of VPNs

Discussion of the benefits of VPNs might revolve around firewalls and whether hardware or software firewalls are best. Students may have opinions about firewall software. VPNs provide a good test of other knowledge. They involve WAN and LAN technology, and are in one sense trying to give the benefits of LAN access across public WAN technology. Issues of functionality, access, security, and cost are primary.

2.1.12 Intranets and extranets

Discuss whether or not the school district has intranet and extranet distinctions. This subject provides a good conclusion for the VPN discussion.

2.2 Bandwidth

Essential Labs: none

Optional labs: none

Core TIs: All

Optional TIs: none

Course-level claim: Describe the meaning and application of the term bandwidth when used in networking.

Hands-on skills: none

2.2.1 Importance of bandwidth

Bandwidth is a critical concept in networking.

2.2.2 Analogies

There are two popular bandwidth analogies presented in this TI, however, more may be added. Vehicle traffic engineering shares some mathematical models with data network engineering.

2.2.3 Measurement

This should be a reinforcement of prior learning in TIs 1.2.2 and 2.1.1. Write the abbreviations on the board and have the students supply as much information as they can. Have students work out problems of converting between the units of bandwidth. Address the common misconceptions about terminology such as, a 10-MB PowerPoint file versus a 10-Mb pipe. The first term refers to 10 megabytes of data. The second term refers to 10 megabits per second of data transfer.

Practice problems

How many Mbps is 40 Gbps?

40 Gbps x 1000 Mbps/1 Gbps = 40,000 Mbps

How many times faster is a T1 line at 1.544 Mbps than a 56 kbps dialup connection?

1,544,000 bits/sec ÷ 56,000 bits/second = 27.6 times faster

The first version of Ethernet in 1973 worked at 2.94 Mbps. 10 Gbps Ethernet is now coming to market. How many times faster is the "10 Gig" Ethernet relative to the original Ethernet?

10,000,000,000 bits/sec ÷ 2,940,000 bits/sec = 3401 times faster!

A video stream is 384 kbps, how many bytes per second are being transferred?

384,000 bits/sec ÷ 8 bits/byte = 48,000 bytes/sec

2.2.4 Limitations

Have samples of media for students to handle at this stage. The IT department is a valuable source for these materials. Have coax and CAT5 cables available with a variety of connectors. One misconception is that optical fiber has unlimited bandwidth. Optical fiber does not have unlimited bandwidth, but it is much higher than current laser sources can be modulated. The copper length limitations pertain especially to attenuation, noise, and timing issues. The fiber length issues involve "bandwidth/distance product" which is primarily due to attenuation and dispersion. That means, that for a given optical fiber construction and light source, the product of bandwidth and distance is fixed. Therefore, longer unrepeatable fiber runs are possible, but at lower bandwidth. Note also that much longer unrepeatable runs of optical fiber are possible. The limits here are to specific, commercialized, well-tested varieties of Ethernet. Ethernet is discussed in great detail in Modules 6 and 7. Do not focus too much on the cable types, other than to point out that the coax, UTP, and fiber versions of Ethernet exist at many different bandwidths.

2.2.5 Throughput

Emphasize the distinction between bandwidth, which is available capacity, and throughput, which is actual bits per second transferred. This distinction will make more sense when the Ethernet frame in Module 6, IP packet in Module 10, and TCP segment in Module 11 are studied.

2.2.6 Data transfer calculation

Using the whiteboard, demonstrate a couple of calculations and then have students perform the calculations. In a real world connection involving a LAN on one end, several WAN connections, and LAN on the other end, the bandwidth of the slowest link in the end-to-end connection would have to be used in the calculation. This is even with the major simplification that assumes servers and device performances are not limiting the transfer speed.

Practice problems

1. An employee in Atlanta begins to download a 20 MB file from Chicago. The data travels from Chicago to Springfield, then to Nashville, then to Atlanta. The links between each location are as follows:

Chicago → Springfield	OC-1
Springfield → Nashville	T1
Nashville → Atlanta	OC-3

Considering the maximum bandwidth for each link, what is the best-estimated download time?

Time = File Size ÷ Lowest Bandwidth

First, convert the file size to bits: $20 \times 1,048,576 \text{ bytes} \times 8 = 167,772,160 \text{ bits}$

Next, plug the values into the formula

Time = $167,772,160 \text{ bits} \div 1,544,000 \text{ bps} \approx 109 \text{ seconds}$

2. Data from a user workstation to a storage area network center takes the following path:

Workstation → IDF	10 Mbps Ethernet over UTP (10BASE-T)
IDF → MDF	100 Mbps Fast Ethernet over Fiber (100BASE-FX)
MDF → SAN	1000 Mbps Gigabit Ethernet over Fiber (1000BASE-LX)

What is the best-estimated time for this user to download a 50 MB curriculum file?

Time = File Size ÷ Lowest Bandwidth

First, convert the file size to bits: $50 \times 1,048,576 \text{ bytes} \times 8 = 419,430,400 \text{ bits}$

Next, plug the values into the formula

Time = $419,430,400 \text{ bits} \div 10,000,000 \text{ bps} \approx 42 \text{ seconds}$

2.2.7 Digital versus analog

The distinction between analog and digital should be reinforced here. Use common devices such as phones and computers to make the distinction. Analog bandwidth is most directly relevant to networking in that cable tests are measured in analog bandwidth, which ultimately limits the digital bandwidth for data transfer. The actual relationship between the measured analog bandwidth and the maximum digital bandwidth of a copper cable requires extensive discussion of the mathematics and practice of cable testing. This subject will be briefly discussed again in Module 4.

2.3 Networking Models

Essential Labs: 2.3.6 and 2.3.7

Optional labs: none

Core TIs: All

Optional TIs: none

Certification-level claim: Describe network communications using layered models

Course-level claim: Describe, compare, and contrast network communications using two examples of layered models.

Hands-on skills: none

2.3.1 Using layers to analyze problems in a flow of materials

This TI introduces the concept of layering and the student begins working on the OSI and TCP/IP models. Analyzing the flow of materials and ideas in terms of layers can help increase the analogies introduced earlier in the course. The student will also be able to understand the idea that communication can be analyzed in layers.

Class activities, where miscommunication is acted out, are a great way to introduce these concepts. There are many examples from everyday life where miscommunication at different layers occurs. Choose a culturally relevant example. One such example in the US is called "At the drive-through restaurant". Using two walkie-talkies and two bilingual students at different ends of the room, have them simulate the drive-through ordering process. One student plays the role of the customer and the other the restaurant employee. First have the student disobey the application layer protocol by ordering chicken at a hamburger restaurant. Then have the student disobey the presentation layer protocol by ordering in a different language. Third, have the student disobey the transport layer protocol by not waiting to have their order repeated back to them and speaking too quickly. Finally have the student disobey the physical layer protocol by talking and not using the walkie-talkies. There are two points that should be made. The first point is that communication can be analyzed in layers and the second is that the layers between the two communicating entities must match. Variations on this theme specific to other cultures are encouraged.

2.3.2 Using layers to describe data communication

Understanding of the concept of peer layers and the process performed by the source and destination devices should be achieved. This is an extension of TI 2.1.5.

2.3.3 OSI model

Emphasize to the students the structure of the OSI model. Have a discussion about the creation of a mnemonic device to aid in recalling the names and order of the layers. Some examples in English are, "Please Do Not Throw Sausage Pizza Away" or "All People Seem To Need Data Processing". Students may ask why there are seven layers. Emphasize that the number of layers is arbitrary, and that seven were chosen in part because of existing technology. Too many layers can add complexity without clarity and too few layers makes the problem less manageable.

2.3.4 OSI layers

Students should be encouraged to re-create the OSI model diagram in their engineering journals and to additionally dedicate a separate page to each layer. As they move through the curriculum they should add to the definition of each layer. Have students commit model and simple definitions to memory. However, true understanding of the layers will only come through other experiences that are both framed by the OSI model and also allow students to construct their own deeper understandings. This is especially true of OSI Layers 1, 2, 3, 4 and 7. All subsequent discussions throughout the courses of CCNA and CCNP are based on this model. It is important for students to be proficient with the OSI layers. Note that technically speaking, according to OSI standards, the physical layer does not include the physical medium itself. The medium is considered outside of the OSI model.

2.3.5 Peer-to-peer communications

With the understanding of the IOS layers from TI 2.3.4, the discussion of this TI should then center on the peer-to-peer process. Teach the names of PDUs and encourage students to commit them to memory. Introduce the encapsulation process. Refer back to the discussion of bandwidth versus throughput. One limiting factor that keeps throughput lower than the maximum bandwidth is that for the network to run properly, the various PDUs carry a variety of addressing and control information.

2.3.6 TCP/IP model

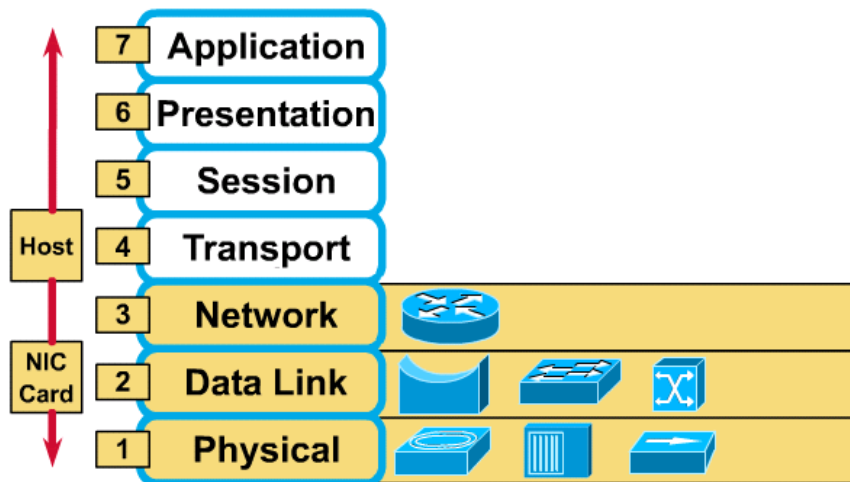
Discuss how the OSI and TCP/IP models match up layer for layer. Promote discussion as to why either model is better. A debate with two or three students on each side is a good exercise. The lab, OSI and TCP/IP Model, is considered optional, though beginning students need to master this knowledge. It could be used as a homework assignment. The networking community settled on the OSI model as the "de jure" standard. However, the TCP/IP protocols dominated and made the TCP/IP model an informal "de facto" standard. Both models have advantages and disadvantages. Many authors, such as Andrew Tannenbaum, like the 5-layer model. This model has the specificity of the lower layers such as the OSI Layer 1 and Layer 2, the layers common to OSI and TCP/IP such as the OSI Layer 3 and 4, known as the network and transport layers, and a Layer 5 application layer from TCP/IP protocol stack.

2.3.7 Detailed encapsulation process

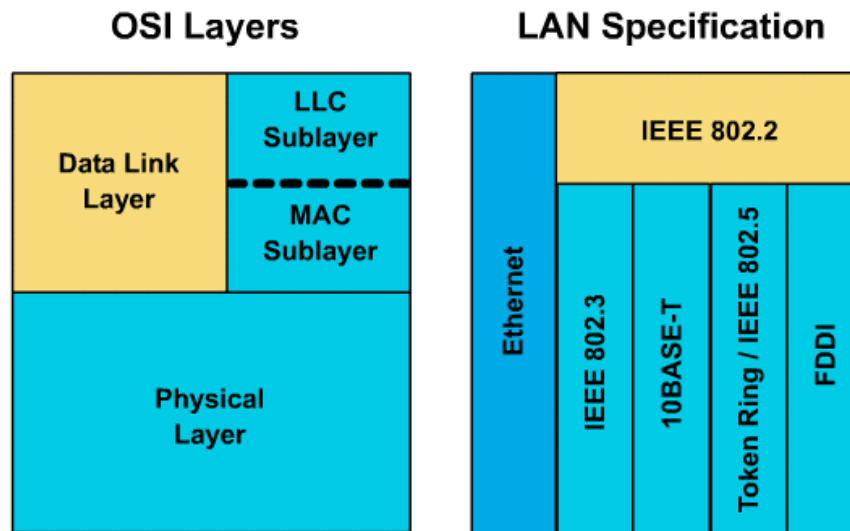
Use analogies to illustrate encapsulation such as the shipment of a large package, which represents data. United Parcel Service (UPS) or any global shipping company can be used. If the package is too large or too heavy, UPS will require it be broken into smaller packages or segmented. The packages need to be addressed, globally (IP) and locally (MAC) and then need to be put on the truck (bits/data stream). A mnemonic in English for this process could be "Drippy Sweet Pancakes For Breakfast", representing Data, Segment, Packet, Frames, and Bits. The lab, OSI Model Characteristics and Devices, is considered optional, though beginning students may need to master this knowledge. It could be used as a homework assignment. Consider a hands on or kinesthetic encapsulation activity such as stuffing and addressing envelopes.

Consider the graphics that follow. Networking devices de-encapsulate and then re-encapsulate at layers depending on the device in question. This concept is of huge importance in networking. Consider having the students draw blank "OSI diagrams" and complete them depending on the topology drawn on the board.

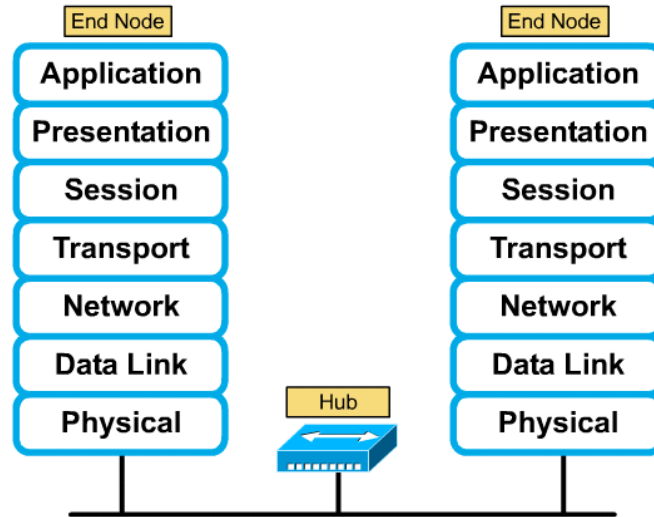
Devices Function at Layers



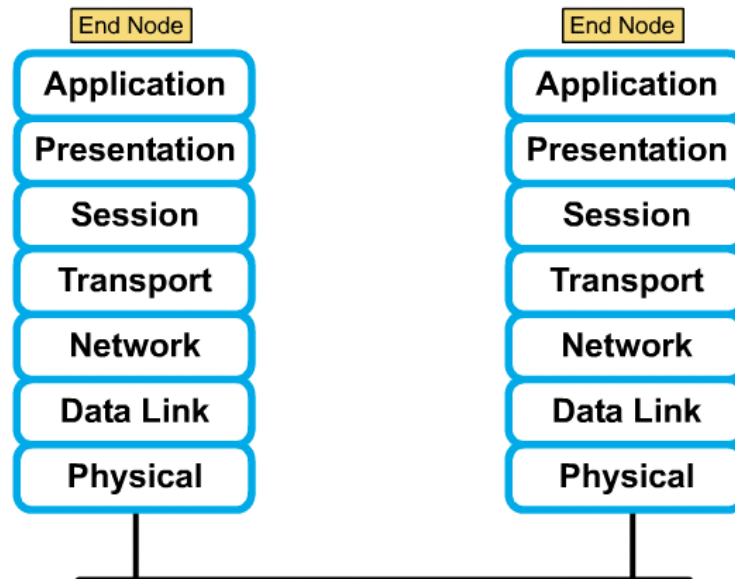
Layer 1 and 2 Segments of the Network



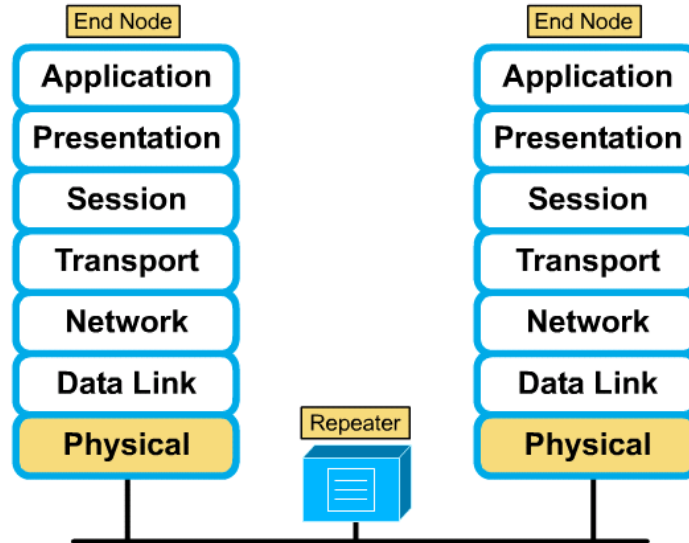
Layer 1 Packet Flow



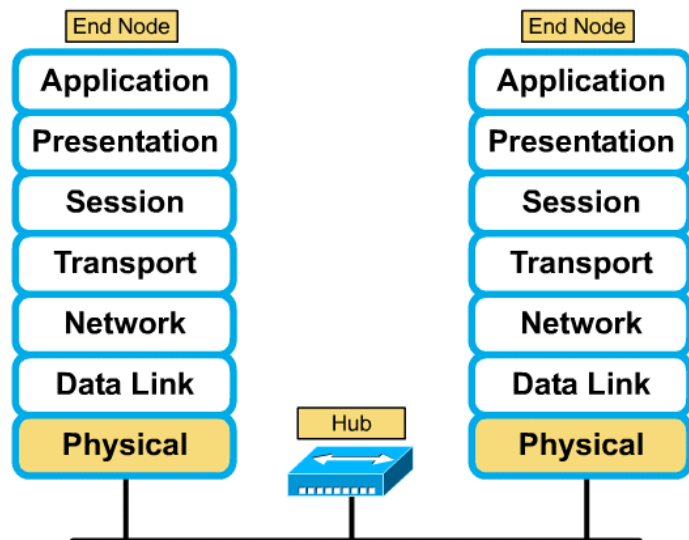
Passive Connection Components



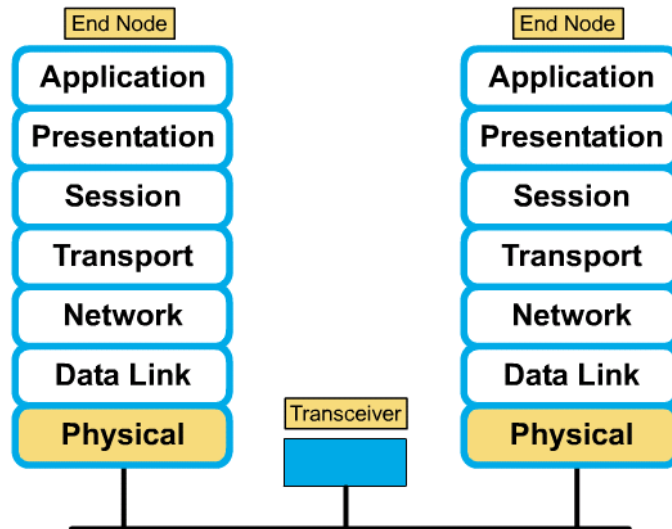
Repeater: Layer 1 Device



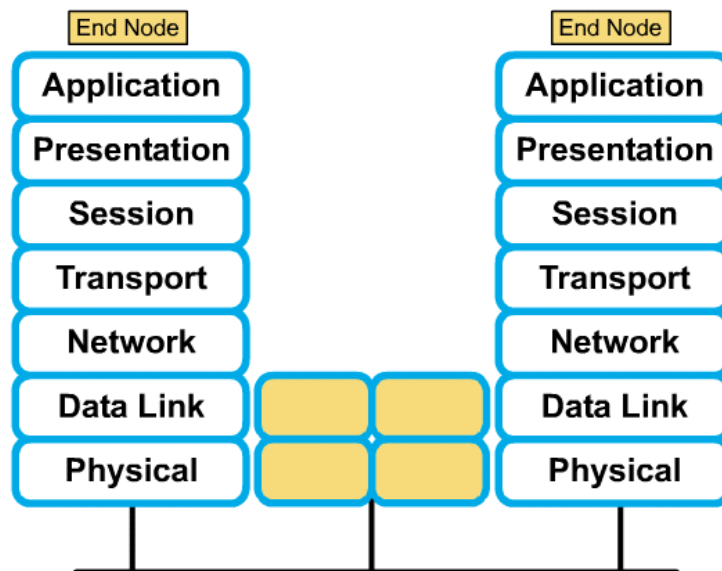
Hub: Layer 1 Device



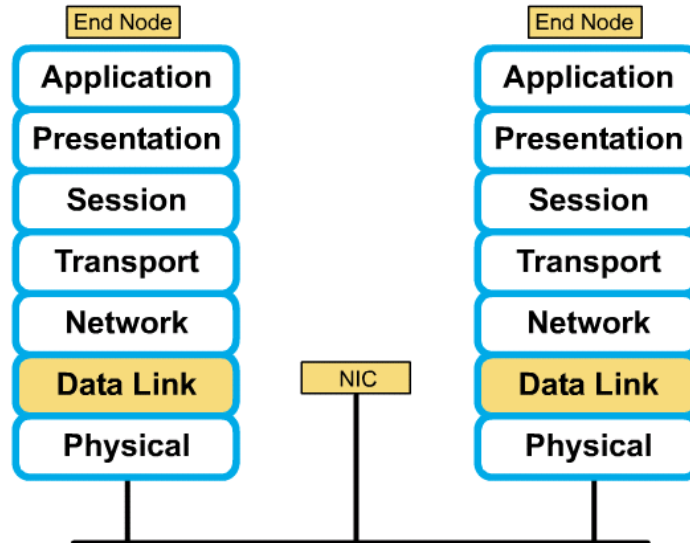
Transceiver: Layer 1 Device



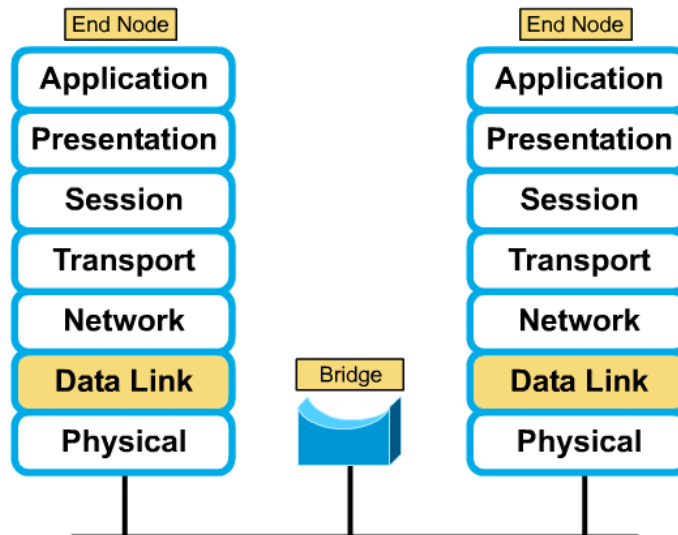
Layer 2 Packet Flow



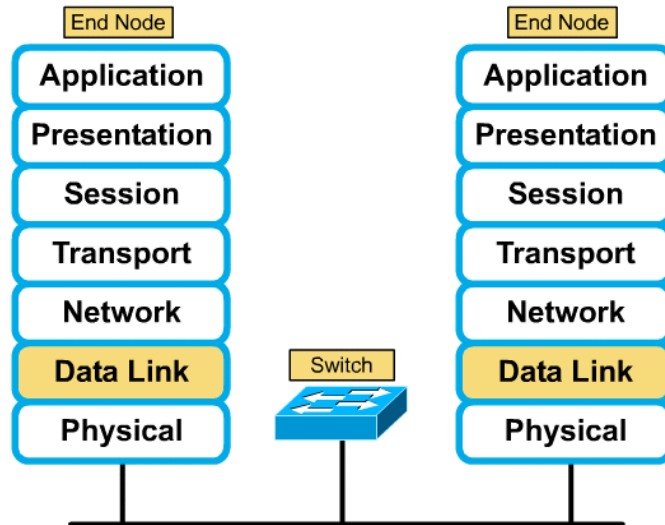
NIC: Layer 2 Device



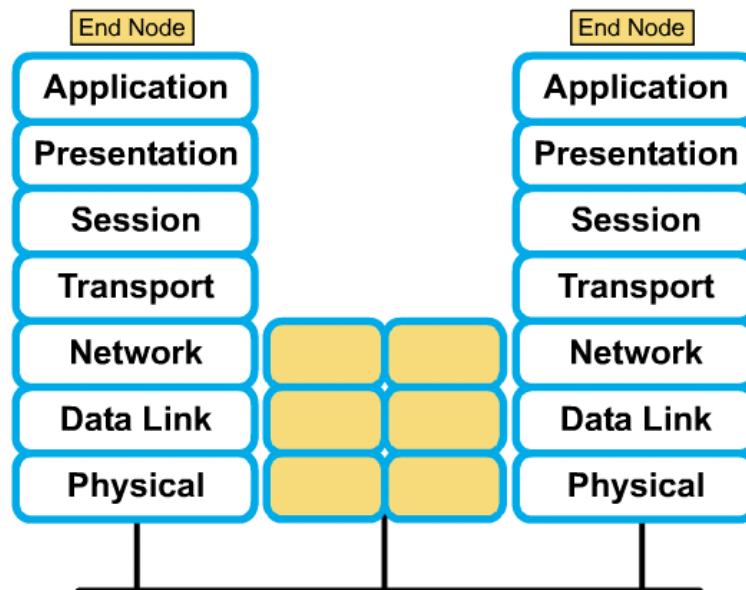
Bridge: Layer 2 Device



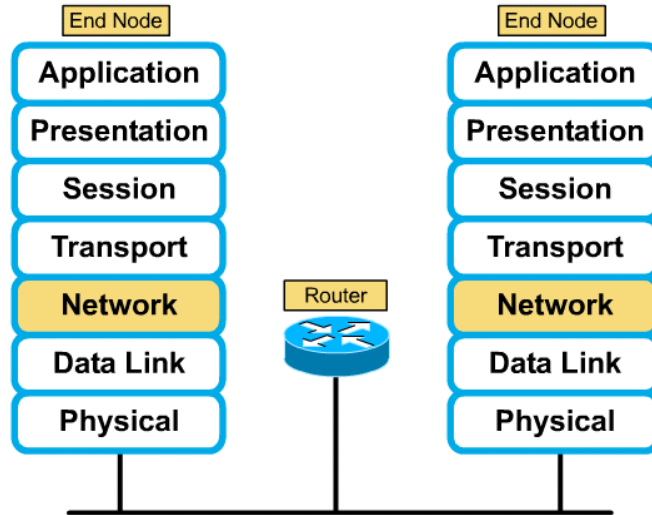
Switch: Layer 2 Device



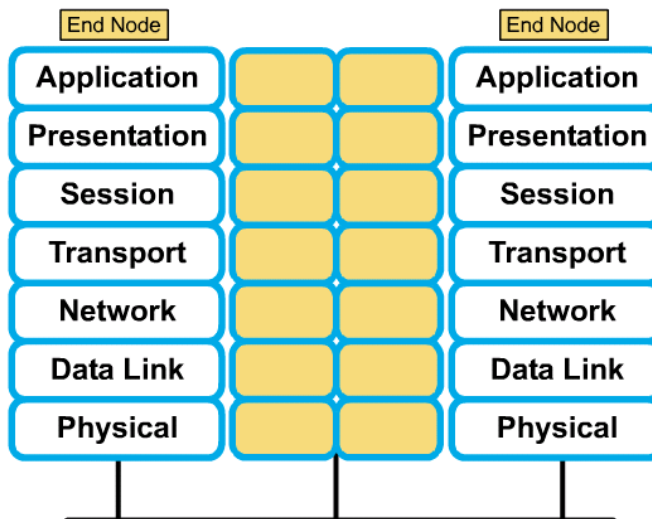
Layer 3 Packet Flow



Router: Layer 3 Device



Packet Flow



Module 2 Summary

Before moving on to Module 3, the students must be proficient in explaining the concept of bandwidth, drawing and labeling from memory the OSI and TCP/IP models, and explaining the encapsulation process.

Online assessment options include the end-of-module online quiz in the curriculum and the online Module 2 exam. Diagramming and sketching assessment options include informal and formal evaluation of drawing network topologies, the OSI model, and simple bandwidth conversion and data transfer calculations. Students should be able to fill in a chart from memory, with headings "Device Name", "Device Symbol", "Device Physical Sketch", "Device OSI Layer", and "Device Function" for workstations, repeaters, hubs, bridges, switches, and routers. Give students the prompt "draw a typical topology and describe the function of a ____ network". This is one way to determine student recall of the terminology of LANs, MANs, WANs, SANs, VPNs, and so on.

Students should understand the following main points:

- LANs and WANs developed in response to business and government computing needs
- Fundamental networking devices are hubs, bridges, switches, and routers
- The physical topology layouts include the bus, ring, star, extended star, hierarchical, and mesh
- A WAN consists of two or more LANs spanning a common geographic area
- A SAN provides enhanced system performance, is scalable, and has disaster tolerance built in
- A VPN is a private network that is constructed within a public network infrastructure
- Three main types of VPNs are access, Intranet, and Extranet VPNs
- Intranets are designed to be available to users who have access privileges to the internal network of an organization
- Extranets are designed to deliver applications and services that are Intranet-based, using extended, secured access to external users or enterprises
- Understanding bandwidth is essential when studying networking
- Bandwidth is finite, costs money, and the demand for it increases daily
- Using analogies like the flow of water and flow of traffic can help explain bandwidth
- Bandwidth is measured in bits per second, kbps, Mbps, Gbps, or Tbps
- Limitations on bandwidth include type of media used, LAN and WAN technologies, and network equipment
- Throughput refers to actual measured bandwidth, which is affected by factors that include number of users on network, networking devices, type of data, the computer and the server
- The formula $T=S/BW$, for transfer time = size of file/bandwidth, can be used to calculate data transfer time
- Comparison of analog and digital bandwidth
- A layered approach is effective in analyzing problems

- Network communication is described by layered models
- The OSI and TCP/IP are the two most important models of network communication
- The International Organization for Standardization developed the OSI model to address the problems of network incompatibility
- The seven layers of the OSI are application, presentation, session, transport, network, data link, and physical
- The four layers of the TCP/IP are application, transport, Internet, and network access
- The TCP/IP application layer is equivalent to the OSI application, presentation, and session layers

Module 3: Networking Media

Overview

When teaching Module 3, emphasize to the students that they are learning all of the major media used in communicating any information anywhere. The two "bounded media" of copper and optical fiber, and the "unbounded" medium of wireless, are the physical basis for the world revolution in communications systems. The challenge of learning more about the basic properties and behavior of networking media can be justified as an interesting and important part of joining the community of networking professionals. Also, the physical reality of the materials and cables discussed is more easily understood than many other topics in networking. This module can be fun for the students, with a variety of hands-on copper cabling labs. Consider other school resources and perhaps call upon the physics department to give a lecture on some of these topics.

Module 3 Caution

This module deals with a fair amount of physics and geometry, which may prove challenging for many students. The many hands-on labs will require preparation by the instructor to be successful. The hands-on labs must be customized to the local learners and their classroom environment. The discussion of frame types in wireless is somewhat premature since Ethernet frame details are not covered until Module 6. This material is presented in more depth than is required for the CCNA certification exam.

Students completing this module should be able to perform the following tasks:

- Discuss the electrical properties of matter
- Define voltage, resistance, impedance, current, and circuits
- Describe the specifications and performances of different types of cable
- Describe coaxial cable and its advantages and disadvantages over other types of cable
- Describe shielded twisted-pair (STP) cable and its uses
- Describe unshielded twisted-pair cable (UTP) and its uses
- Discuss the characteristics of straight-through, crossover, and rollover cables and where each is used
- Explain the basics of fiber-optic cable
- Describe how fibers can guide light for long distances
- Describe multimode and single-mode fiber
- Describe how fiber is installed
- Describe the type of connectors and equipment used with fiber-optic cable
- Explain how fiber is tested to ensure that it will function properly
- Discuss safety issues dealing with fiber optics

3.1 Copper Media

Essential Labs: 3.1.5, 3.1.9a, 3.1.9b, 3.1.9c, 3.1.9d, 3.1.9e, and 3.1.9f

Optional labs: 3.1.1, 3.1.2, and 3.1.3

Core TIs: All

Optional TIs: none

Course-level claim: Describe the physical, electrical, and mechanical properties and the standards associated with copper media used in networks.

Hands-on skills: Students can efficiently make and test Category 5 straight-through, crossover, and rollover cables.

3.1.1 Atoms and electrons

Why is the periodic table included in this module? Understanding conductors, semiconductors, and insulators, which are the primary materials for building copper-based networks, is greatly facilitated by reference to the table. The table helps connect new knowledge to what may be prior knowledge. Referring to the table aligns with many educational standards and is part of a well-rounded science and technical education. Discuss ESD and simple ways to avoid problems without using grounding stations. For example, like avoiding polyester or wool clothing, working on non-carpeted surfaces, and touching a chassis and then not moving while working. The lab "Safe Handling and Use of a Multimeter" is an optional introduction to a series of hands-on electronics labs important for certain student populations.

3.1.2 Voltage

The concept of voltage is crucial for many networking topics. It is important to know about signals and noise, voltages in devices, voltages for power, and voltages as sources of damage. The lab "Voltage Measurement" is optional, but recommended to make these topics more hands-on for integration with electronics programs.

3.1.3 Resistance and impedance

This TI focuses on a limited discussion of conductors, semiconductors, and insulators. The lab "Resistance Measurement" is optional.

3.1.4 Current

Networks are fundamentally electronic systems. Optical and wireless devices are also electrical. This TI provides more basic vocabulary. Amperage is most commonly encountered in dealing the power requirements of networks, and could be a part of the case study.

Practice problem

Calculate the wattage from the following voltages and amperages:






($P=VI$: Power = Volts x Amps)

- | | |
|-------------------|--------------------------------------|
| 1. 120 V, 60 Amps | $120 \times 60 = 7200 \text{ watts}$ |
| 2. 9 V, 0.06 Amps | $9 \times 0.06 = 0.54 \text{ watts}$ |
| 3. 5 V, 0.1 Amps | $5 \times 0.1 = 0.5 \text{ watts}$ |
| 4. 12 V, 2 Amps | $12 \times 2 = 24 \text{ watts}$ |
| 5. 3 V, 0.05 Amps | $3 \times 0.05 = 0.15 \text{ watts}$ |

3.1.5 Circuits

An electrical circuit is a fundamental idea that is the basis of many concepts and symbols in networking. The knowledge in RIOs 3.1.1 through 3.1.5 may be complex for beginning students and trivial for advanced students. Use this TI as a measurement of knowledge. Make sure the students have a good understanding on the concept of a circuit. If not, they will understand less of the Ethernet sections, not just for cabling, but for concepts like collisions. They will understand less of the concepts like "circuit-switched versus packet-switched" or proper grounding of networking systems. The series of Figures 1 through 4 introduces terminology used throughout the CCNA curriculum. The lab "Series Circuits" is required though instructors are encouraged to implement it in a manner appropriate to the knowledge level of the students. The "Communications Circuits" lab, 3.1.9a, could also be conducted here.

Summary Graphic

-  Electrons flow in closed loops called circuits
-  Definitions
 - Voltage:** Electrical pressure due to the separation of electrical charge. (+ and -)
 - Current(I):** Flow of charged particles, usually electrons
 - Resistance:** Property of a material that opposes, and can control electrical flow.
 - Impedance:** Equivalent to resistance but for AC and pulsed circuits.
 - Short Circuit:** Conducting path.
 - Open Circuit:** Discontinuity in conducting path.
-  Voltage causes currents; resistance and impedance limit currents
-  Network Cabling: contains many circuits
-  Network Devices: contains millions of circuits

3.1.6 Cable specifications

Ethernet has not been introduced formally at this point, so be prepared for other questions. The graphic from TI 2.2.4 may be useful here. Emphasize the graphic and the significance of each part of the specification name. The principle idea is that the media and terminations are governed by standards and specified within the dominant LAN technology, Ethernet. This will be covered in great detail in Modules 6 and 7.

3.1.7 Coaxial cable

Obtain samples of coax cable and pass them around the class. Obtain some BNC connectors including T-connectors, barrel connectors, and terminators to show students how coax cable connects to the various devices. Compare the coax to cable TV. Also discuss the issues of cabling, including cost, ease of installation and maintenance, noise immunity, and length and bandwidth limitations.

3.1.8 STP cable

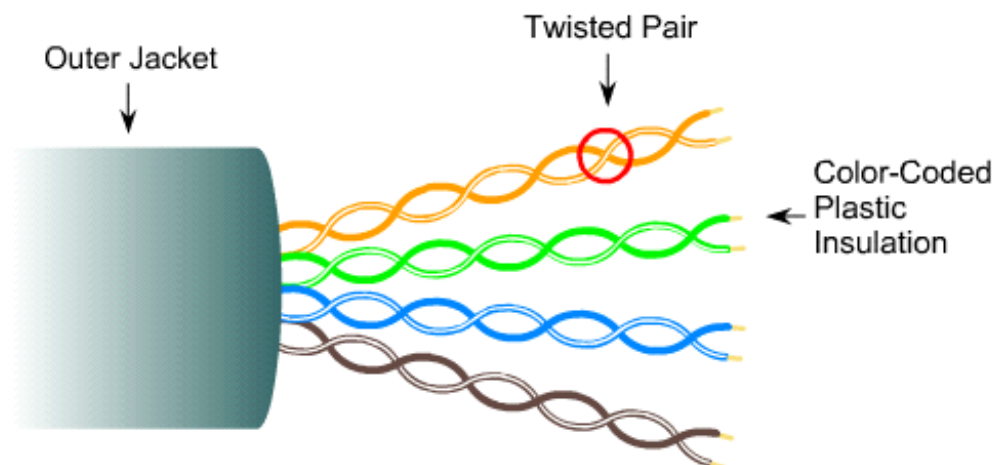
If possible, obtain samples of STP cable and pass them around. Discuss, in simple terms, electromagnetic induction. This may make the idea of crosstalk more plausible. For example, time-varying electromagnetic fields, either due to electromagnetic waves from sources outside the cable or other wires in the cable, are why the shielding has been developed. Again, discuss the issues of cabling, including cost, ease of installation and maintenance, noise immunity, and length and bandwidth limitations.

3.1.9 UTP cable

This is an extremely important TI, with an enormous amount of material in it. Again, discuss the issues of cabling, including cost, ease of installation and maintenance, noise immunity, and length and bandwidth limitations. Perform the cable making labs. This TI can be deceptive. It has five Essential Labs and should be given enough class periods for in-depth coverage. These labs contain core knowledge for CCNA 1 students. First, do the "Communications Circuits" lab, a constructivist introduction to many issues that arise throughout the curriculum. This lab serves two purposes. It familiarizes students with UTP. Second, it sets up the discussion of layers, specifically issues of bits and framing important in later modules. The lab can be quite fun and stimulate positive classroom interactions.

Then students should, using whatever tester is available, do the second lab, "Fluke 620 Basic Cable Testing". This will increase their awareness of what they are about to build and provides a good starting point for discussions on workmanship and standards.

Have students build and test their straight-through, rollover, and crossover cables. Building cables is a valuable lab skill. It also increases awareness of physical medium and Layer 1 issues, an area of much troubleshooting by CCNAs who are employed in the industry. For example, Layer 1 issues occur when troubleshooting a cable run in an office. The source NIC, the patch cable in the work area, the jack, the wires in the cable run, the connector pinouts, the patch panel, and switch interface on the other end could all be issues. Successful hands-on cabling labs also provide a profound sense of accomplishment for a wide variety of students. Instructors are encouraged to combine these labs to better accommodate their teaching schedule. It is the finished products and end skills that matter. The lab "UTP Cable Purchase" is optional. It could be done as homework, just encourage the students to view the latest cabling information. Siemon, Panduit, Microwarehouse, and many other vendors all have interesting websites with this cabling information. See also the PhotoZooms in 5.1.5.



3.2 Optical Media

Essential Labs: none

Optional labs: 3.2.8

Core TIs: 3.2.1 and 3.2.6

Optional TIs: 3.2.2, 3.2.3, 3.2.4, 3.2.5, 3.2.7, 3.2.8, 3.2.9, and 3.2.10

Course-level claim: Describe the physical, electrical and mechanical properties, and standards associated with optical media used in networks.

Hands-on skills: none

3.2.1 The electromagnetic spectrum

Try to introduce this lesson by having samples of optical fiber. If possible, have a small light for illuminating the fiber as the students handle it. Students may be amazed that optical fiber, even while curled, acts as a "light pipe". The IT department is a valuable source for these materials.

The Electromagnetic (EM) Spectrum chart, like the periodic table of the elements, is of tremendous importance in science and engineering. It does require careful reading. To show all of the powers of ten, the horizontal scale on the spectrum chart is logarithmic, not linear. That is, 1, 10, 100, and so on are the powers of ten. The intervals 1 to 10, 10 to 100, 100 to 1000, and so on are shown as equal distances on the horizontal axis. Have students look up the frequency and wavelength ranges for microwaves, where 2.4 GHz and 5 GHz are used for wireless LANs, and infrared, where the range of 870 to about 1500 nm is used for optical communications. The wavelength and frequency of all EM waves in vacuum is governed by the formula wavelength (in meters) x frequency (in hertz) = c, the speed of light in vacuum (in meters/second). Therefore, higher frequency waves have shorter wavelengths and lower frequency waves have longer wavelengths. The speed of light could be more properly described as the speed of all electromagnetic waves in vacuum.

Another question that may arise is "Which is faster, copper, optical, or wireless?" A distinction must be made between the speed at which the networking signals travel from Point A to Point B and the bandwidth of the media that many refer to as the "speed of the network". Voltage waves on copper cables and light waves in the glass or plastic of optical fiber travel at about 67% of the speed of light in vacuum. Microwaves in air travel about 99% of speed of light in vacuum. But these speeds, also called the nominal velocity of propagation in cable testing, do not represent the other use of the word "speed", meaning bandwidth, in networking. Students should be referred to any introductory physics book if they wish to learn more about these waves. This includes alternating electric and magnetic fields, which require no medium in which to propagate.

3.2.2 Ray model of light

Use a light bulb and, if possible, a laser pointer to demonstrate the idea of rays. Caution is advised whenever using any laser device. Care should be given when demonstrating with laser sources to protect vision. The term "index of refraction" literally means the medium-dependent measure of how much light slows down in an optically transparent material. Higher index will mean lower speed for light in that material. When a light ray is traveling at an angle and hits a boundary between two materials, "n" gives an index of how much refraction or bending the light will undergo. Students do not need to memorize any of the numbers. Only vacuum has an index of exactly 1.00000. Air is actually about 1.0003, so light does slow down a bit in air.

Practice problems

Calculate the index of refraction "n" for each of these substances:

Speed of light in a vacuum = c = 299,792,458 m/s

($n = c \div \text{speed of light in an optically transparent material}$)

Air=299,705,543 m/s $299,792,458 \div 299,705,543 = 1.00029$

Ice=228,849,204 m/s $299,792,458 \div 228,849,204 = 1.31$

Water=225,407,863 m/s $299,792,458 \div 225,407,863 = 1.33$

Glass=199,861,638 m/s $299,792,458 \div 199,861,638 = 1.50$

If the Index of Refraction of a fiber optic cable is 1.497, how fast does light travel through it?

$n=1.497$ $299,792,458 \div 1.497 = 200,262,163$ m/s

3.2.3 Reflection

Carefully introduce the terminology used for optics such as interface, normal, ray, angles, theta as a symbol, angle of incidence, and angle of reflection. In optics, all angles are measured relative to the normal. This could cause confusion for beginning students. Reflection can be demonstrated, very carefully, using a laser pointer and a mirror. Tell students to devise an experiment using a mirror that illustrates this principle. An analogy to the reflection of pool balls may be useful here. Light incident on a totally mirrored surface is completely reflected. The light shown in the figure is incident on a glass surface, so some is reflected and some is refracted. For simplicity, the refracted ray is not shown in this diagram.

3.2.4 Refraction

Three rays are shown for this general case of light traveling between two optically transparent materials. The incident ray contains all of the light energy. In general this energy is divided between a reflected ray and a refracted ray. Snell's Law relates the index of refraction to the angles involved, and describes this phenomenon. Refraction occurs in a human eye and any eyeglasses or contact lenses. Single-ray refraction can be shown with a laser pen in a darkened room. Point the laser pen at an angle to a rectangular-shaped clear plastic container with water, such as a small aquarium. Have a small amount of milk in the container to scatter the light for viewing.

3.2.5 Total internal reflection

The purpose of this TI is to demonstrate the concept of light pipes and wave guiding. Students are not expected to achieve any great understanding of this difficult-to-understand phenomenon. It is described to cause wonder and make plausible the basic mechanism of the increasing presence of optical fiber.

Have students look at the three different incident rays as a series that is approaching a limit. That is, to observe rays at different angles that partially reflect and refract until a certain angle, the critical angle, causes the refracted ray to do something odd. It travels at 90 degrees to normal, along the interface. For a light incident where the interface is at angles greater than the critical angle, the refracted ray ceases to exist. This situation is called Total Internal Reflection, or TIR. The critical angle for TIR depends on the two materials involved, and is about 41 to 42 degrees for most forms of glass and plastic relative to air.

TIR is a desirable condition. It provides a means of trapping and guiding light. There is no TIR for rays of light going from low index material to high index material. Therefore, the most basic requirement for trapping or guiding light, as in an optical fiber, is that the material in which the rays are to be trapped has a greater index of refraction than the external material. An example of TIR would be when a swimmer, swimming underwater, looks up at the surface at certain angles and is not able to see out of the water. A laser pen and an aquarium as described in TI 3.2.5 can be used to illustrate TIR. A lucite rod can work as well.

The goal of optical media in a computer network is to get all light rays totally internally reflected so the energy can travel further down the fiber. Even if all rays are launched within the numerical aperture, so that they travel down the fiber, energy is still lost due to absorption and scattering. The rays will spread out in time due to dispersion. Therefore, there are physical limits even to the length of optical fiber runs, but these limits are in the hundreds of kilometers.

3.2.6 Multimode fiber

The purpose of this TI is to understand the difference between single and multimode fiber. Use a fiber optic patch cable, and use either a small flashlight or a laser pen to show how the far end of the fiber is illuminated, even when the fiber is coiled.

3.2.7 Single-mode fiber

This TI provides more detail on single-mode fiber to help distinguish it further from multimode. The ray in a single-mode fiber does not literally go straight down the core, but rather one mode, or one set of paths, is supported. If more than one mode was allowed, the ray path that has more bounces would be delayed in time from the ray path with less bounces. This disperses the pulse in time, ultimately making binary ones and zeros indistinguishable and limiting the length and data transfer rate of the fiber.

3.2.8 Other optical components

This material is meant to provide background motivation in this area for some students to pursue further learning. The lab “Fiber-Optic Cable Purchase” is optional and is just meant to increase the knowledge of real world optical fiber.

3.2.9 Signals and noise in optical fibers

Focus the discussion in this TI, on the fact that fiber is not affected by the external noise or noise from other cables in the bundle. Light confined in one fiber has no way of inducing light in another fiber. Lack of induction from outside a given fiber is why fiber is described as immune to noise. The electronics on both ends of the fiber are not immune to noise. There is no such thing as a communications system without noise, so relative noise immunity is a more accurate description.

3.2.10 Installation, care, and testing of optical fiber

In this TI, it is best to find a local installer that would be willing to come in and do a demonstration. Again, this is background information on the media issues particular to optical fiber. While these lab skills are not taught as part of CCNA, they are taught as part of the Academy Fundamentals of Voice and Data Cabling (FVDC) course. Depending on local needs and resources, some Academies do teach some fiber termination and testing.

3.3 Wireless Media

Essential Labs: none

Optional labs: none

Core TIs: 3.3.1 and 3.3.2

Optional TIs: 3.3.3, 3.3.4, 3.3.5, 3.3.6, and 3.3.7

Certification-level claim: Describe the standards and properties associated with the transmission and reception of wireless signals used in networks.

Course-level claim: Describe what is required to install a simple WLAN.

Hands-on skills: none

3.3.1 Wireless LAN organizations and standards

Students should be able to differentiate between the various standards. They should begin to understand issues of compatibility and incompatibility, speeds, and transmission bands. The references to IEEE standards precede the in-depth discussion of IEEE Ethernet standards in Module 6. Furnish the students with more context about the 802 LAN and MAN standards or revisit the discussion in Module 6. Correct the widespread misconception that wireless LANs are a form of Ethernet. WLANs are governed by the same IEEE 802 standards and have been explicitly designed to interoperate with Ethernet LANs, but they are not a form of Ethernet.

3.3.2 Wireless devices and topologies

This is another area where a small investment in a couple of wireless NICs and an access point can help the student understand. A WLAN may be accessible somewhere in the school. The main idea is to add the wireless devices to the collection of LAN technology options. WLANs are becoming ever present as LAN extensions.

3.3.3 How wireless LANs communicate

If the equipment is available and the NICs came with software that tests the strength of the signal, experiment with moving the wireless cards further and further from the access point. The signal will weaken and then lose connectivity. Students should know what a frame is generally. However, they will have no sense of the complexity of Ethernet frames as are referred to in this TI. The detailed discussion of frames here is premature. Proceed to Module 6 for more information, or just lightly look over this section of the curriculum. A key issue here is the tradeoff between data transfer rate and distance.

3.3.4 Authentication and association

Have the students take note of the frame types in the graphic and the definitions in the text frame. The most important issue here is that wireless is an unbounded media. The medium is the air in which the microwaves travel. It is a shared medium open to anyone with microwave receivers or detectors. The security of signals is of primary importance and concern. Some students who are apartment dwellers may have the experience of detecting signals from other wireless systems in the apartment complex. At times, unintended access to an Internet connection may be obtainable. The Cisco headquarters located in San Jose, California has a wide street in the campus, where a light rail train runs through the middle. Insecure wireless connections are available on the train.

3.3.5 The radio wave and microwave spectrums

The animations can be used to demonstrate transmission. They also reinforce the information gained from any simple wireless demonstrations performed. A new Cisco Academy course dealing with wireless LANs covers all of this material in great depth. Have the students revisit the electromagnetic spectrum chart. Recall the fact that the spectrum is a precious regulated resource, in which certain bands have been left unregulated spurring medical, scientific, and commercial technology development. Spectrum regulations and standards differ around the world. Students could be asked to investigate their local spectrum allocations.

3.3.6 Signals and noise on a WLAN

Research Bluetooth Technologies at <http://www.bluetooth.com>. Ask the students why many wireless locations require that Bluetooth devices be turned off before users enter the premises. Emphasize the ubiquity of electromagnetic wave signals in the classroom from TV, radio, WLANs, satellites, and many other sources.

3.3.7 Wireless security

Students should know the various security protocols. This is qualitative background information.

Module 3 Summary

Before moving on to Module 4, the students must be proficient in describing copper, optical fiber, and wireless networking media options. They should be able to make straight-through, crossover, and rollover cables.

Online assessment options include the end-of-module online quiz in the curriculum and the online Module 3 exam. Consider having students create comparison and contrast charts of copper, optical, and wireless media.

Students should understand the following main points:

- All matter is composed of atoms, and the three main parts of an atom are protons, neutrons, and electrons. The protons and neutrons are located in the center part of the atom, which is called the nucleus.
- Electrostatic discharge (ESD) can create serious problems for sensitive electronic equipment.
- Attenuation refers to the resistance to the flow of electrons and why a signal becomes degraded as it travels.
- Currents flow in closed loops called circuits, which must be composed of conducting materials and must have sources of voltage.
- A multimeter is used to measure voltage, current, resistance, and other electrical quantities expressed in numeric form.
- Three types of copper cables used in networking are straight-through, crossover, and rollover.
- Coaxial cable consists of a hollow outer cylindrical conductor that surrounds a single inner wire conductor.
- UTP cable is a four-pair wire medium used in a variety of networks.
- STP cable combines the techniques of shielding, cancellation, and twisting of wires.
- Optical fiber is a very good transmission medium when it is properly installed, tested, and maintained.
- Light energy, a type of electromagnetic energy wave, is used to transmit large amounts of data securely over relatively long distances.
- The light signal carried by a fiber is produced by a transmitter that converts an electrical signal into a light signal.
- The light that arrives at the far end of the cable is converted back to the original electrical signal by the receiver.
- Fibers are used in pairs to provide full-duplex communications.
- Light rays obey the laws of reflection and refraction as they travel through a glass fiber, which allows fibers with the property of total internal reflection to be manufactured.
- Total internal reflection makes light signals stay inside the fiber, even if the fiber is not straight.
- Attenuation of a light signal becomes a problem over long cables especially if sections of cable are connected at patch panels or spliced.

- Cable and connectors must be properly installed and thoroughly tested with high quality optical test equipment.
- Cable links must be tested periodically with high quality optical test instruments to check whether the link has deteriorated in any way.
- Care must always be taken to protect eyes when intense light sources like lasers are used.
- Understanding the regulations and standards that apply to wireless technology will ensure that deployed networks will be interoperable and in compliance.
- Compatibility problems with NICs are solved by installing an access point (AP) to act as a central hub for the WLAN.
- Three types of frames are used in wireless communication: control, management, and data.
- WLANs use Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA).
- WLAN authentication is a process that authenticates the device, not the user.

Module 4: Cable Testing

Overview

When teaching Module 4, emphasize to the students that much of the terminology used in this module is invaluable. It is broadly applicable to copper, optical, and wireless networking systems. Cisco products are particularly focused on Layers 2 through 4, so the certification reflects some of this emphasis. Details about cable testing are not on the CCNA certification exam. However, it is an important background for understanding the Layer 1 troubleshooting issues that industry repeatedly indicates are a primary concern of CCNA-certified personnel. Estimates range as high as 70 percent of CCNA-level troubleshooting tasks involve the physical medium and OSI Layer 1. Module 4 introduces crucial terminology and concepts for understanding frequency-based cable testing, important in understanding both copper cables and optical fiber.

Module 4 Caution

The mathematics in this module does not need to be mastered. However, some students may be intimidated. The physics of crosstalk is not obvious. There are insufficient graphics used to describe the cable-testing lesson.

Students completing this module should be able to perform the following tasks:

- Differentiate between sine waves and square waves
- Describe exponents and logarithms
- Describe decibels
- Define basic terminology related to time, frequency, and noise
- Differentiate between digital bandwidth and analog bandwidth
- Compare and contrast noise levels on various types of cabling
- Define and describe the affects of attenuation and impedance mismatch
- Define crosstalk, near-end crosstalk, far-end crosstalk, and power sum near-end crosstalk
- Describe how crosstalk and twisted pairs help reduce noise
- Describe the ten copper cable tests defined in TIA/EIA-568-B
- Describe the difference between Category 5 and Category 6 cable

4.1 Frequency-Based Cable Testing

Essential Labs: none

Optional labs: none

Core TIs: 4.1.1, 4.1.2, 4.1.6, and 4.1.8

Optional TIs: 4.1.3, 4.1.4, 4.1.5, and 4.1.7

Course-level claim: Explain the issues associated with the transmission of signals on networking media.

Hands-on skills: none

4.1.1 Waves

Make sure the students can define hertz. A "slinky" spring toy is good for showing both longitudinal waves of compression and rarefaction and transverse waves with vibrations perpendicular to the direction of travel.

4.1.2 Sine waves and square waves

Ask if the physics or electronics departments have equipment to demonstrate sine and square waves. Consider having students draw examples of waves of differing amplitudes and frequencies and labeling their drawings.

4.1.3 Exponents and logarithms

Review the powers of ten that were covered in Module 1. Students should find working with metric prefixes and exponents for expressing bits, bytes, and bits per second easier at this point. Students are not expected to master logarithms. Logarithms are just background material. The Flash activities are for discovery purposes.

4.1.4 Decibels

The decibel, is perhaps most familiar as a measure of sound intensity. It is also used to describe all networking signals, whether voltage waves on copper, optical pulses in fiber, or microwaves in a wireless system. Students are not expected to master the formula, just to recognize that decibels are the key measure of signal and noise in all communications systems. Decibels are a relative measure. There is always some reference voltage or power level in the denominator of the formula. Note that if the final voltage or power is greater than the reference level, the result is positive or a gain. If the final voltage is less than the reference level, the result is negative or a loss.

Practice problems

Figure what the "final" strength would be if given dB and "ref"

$$P_{\text{final}} = P_{\text{ref}} \times 10^{(\text{dB}/10)} \text{ or } V_{\text{final}} = V_{\text{ref}} \times 10^{(\text{dB}/20)}$$

$$P_{\text{ref}} = P_{\text{final}} \times 10^{-(\text{dB}/10)} \text{ or } V_{\text{ref}} = V_{\text{final}} \times 10^{-(\text{dB}/20)}$$

1. 10 millivolts are measured at the end of a cable. The source voltage was 1 volt. What is the gain or loss in decibels?

$$\text{dB} = 20 \times \log_{10} (0.01 \div 1) = -40\text{dB}$$

2. 60 microvolts are measured at the end of a cable. The source voltage was $\frac{1}{2}$ volt. What is the gain or loss in decibels?

$$\text{dB} = 20 \times \log_{10} (0.00006 \div 0.5) = -78.41\text{dB}$$

3. 37 milliwatts of power remain at the end of a fiber optic cable. The original amount of power sent was 80 milliwatts. What is the gain or loss in decibels?

$$\text{dB} = 10 \times \log_{10} (0.037 \div 0.080) = -3.34\text{dB}$$

4. 5 volts are sent on a cable, but the voltage measured at the end is 10 volts. What is the gain or loss in decibels?

$$\text{dB} = 20 \times \log_{10} (10 \div 5) = 6.02\text{dB}$$

5. If 5 volts are sent, and the maximum amount of loss can be no greater than 5 dB, what is the minimum allowable voltage at the end of the cable?

$$V_{\text{final}} = 5 \times 10^{(-5/20)} = 3.15 \text{ volts}$$

6. If the power of a signal sent by an LED is 5 milliwatts, and the maximum amount of power loss can be no greater than 10 dB, what is the minimum allowable amount of power at the end of a fiber optic cable?

$$P_{\text{final}} = .005 \times 10^{(-10/10)} = .5 \text{ milliwatts}$$

4.1.5 Time and frequency of signals

The key point here is that the study of signals in networking uses two primary representations. One is a picture of what is happening in time and the other is a picture of how different signal frequencies relate.

The voltage versus time graph is implicit in many graphical representations of networking. Starting with a voltage or power versus time graph of a single bit, consider then a stream of bits, then a frame, then a packet, and finally a segment. The most important PDUs being the Ethernet frame, the IP Packet, and the TCP segment, derive from this most basic of representations, the voltage or power versus time graph.

An FM radio dial is one analogy for understanding the frequency domain. Graphing signal strength estimated by how strong a given radio station comes in, versus frequency for the range 87 to 107 MHz, would produce a graph of signal strength (power) versus frequency, as would be displayed on a spectrum analyzer device. The frequency spacing, for example 0.2 MHz, on a digital FM tuner, gives some indication of an upper bound on the bandwidth of each radio station.

4.1.6 Analog and digital signals

Reinforce the difference between analog and digital as previously learned in the course. The three basic properties of a sine wave are its amplitude, frequency, and phase. Amplitude is height above and below the x-axis. Frequency is the reciprocal of the period of time to complete one wave cycle. The phase is a measurement of the delay of the wave relative to some fixed reference point or another sine wave.

Most modern telecommunications consists of modulating either amplitude, frequency, or phase. Students are not expected to master the mathematics. This TI is trying to show that the digital square waves that comprise the networking signals can be thought of as a carefully constructed sum of sine waves. Therefore, cable testing can use sine waves at different frequencies measured in hertz, which is an analog approach, to determine the maximum data transfer supported on a cable as measured in bps, kbps, Mbps, Gbps, a digital approach.

4.1.7 Noise in time and frequency

Using an oscilloscope is an excellent way to demonstrate interference. Turn on the oscilloscope and then run another electrical device near it to see the effect.

Ampere's Law states that any electrical current is surrounded by a magnetic field. Therefore, any time-varying electrical current is surrounded by a time-varying magnetic field. Faraday's Law states that any time-varying magnetic field induces a voltage in "nearby" conducting materials. For that reason, it is normal that adjacent wires produce crosstalk and that external electrical and magnetic fields that cross wires will induce voltages on those wires. Long wires increase this effect and act as antennas, both radiating and receiving signals whether or not that is intended.

Different forms of noise occur in optical fiber systems. Students do not need any of this detail. The main points are that noise is the rule, not the exception. Noise can be looked at either in time or in frequency, and that networking technologies and installations must take noise into account.

4.1.8 Bandwidth

This is a review of TI 2.2.3. The actual relationship between cable testing frequencies measured in hertz and digital bandwidth measured in bps is a complex subject beyond the scope of this course. For example, Category 5e tests to 155 MHz yet 1000 Gbps Ethernet can operate over it. How bits are encoded and decoded, how many wire pairs are used, and the physical properties of a medium determine this relationship. For more information, go to <http://www.flukenetworks.com/>.

Explain that bandwidth does not equal throughput. Students know that if they have a 56K modem, that they never actually get 56K. Sometimes the bandwidth is like the speed limit on a road. For example, a satellite ISP states that 400K downloads are available. As on a highway, sometimes traffic moves much faster, but sometimes it cannot because of traffic congestion.

4.2 Signals and Noise

Essential Labs: 4.2.9a

Optional labs: 4.2.9b, 4.2.9c, 4.2.9d, and 4.2.9e

Core TIs: 4.2.1, 4.2.2, 4.2.3, 4.2.4, and 4.2.5

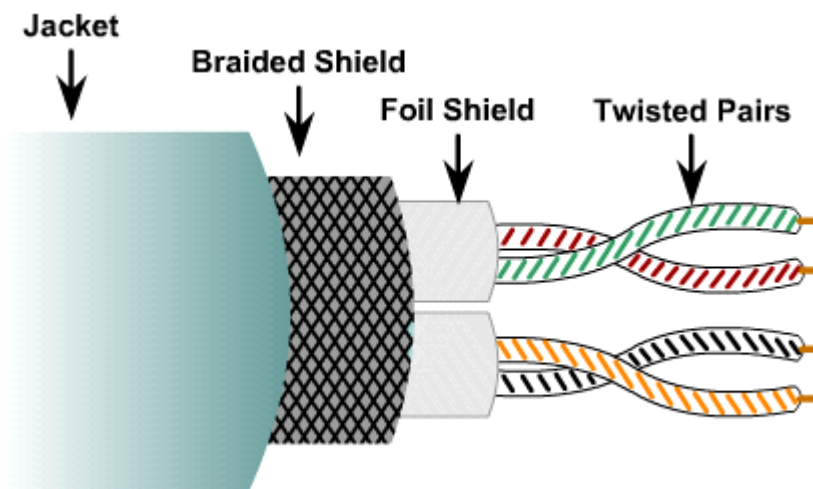
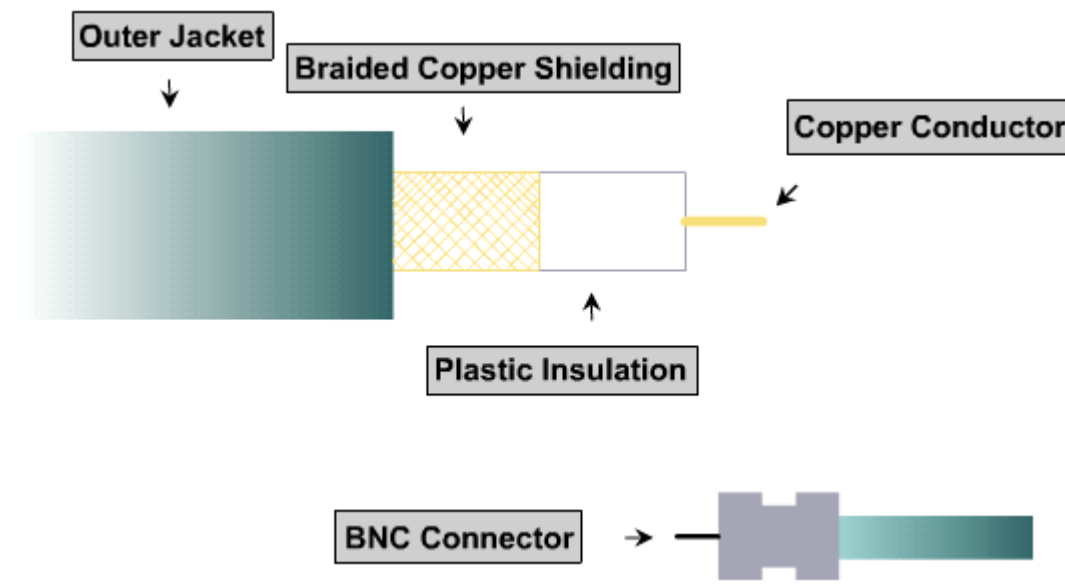
Optional TIs: 4.2.6, 4.2.7, 4.2.8, and 4.2.9

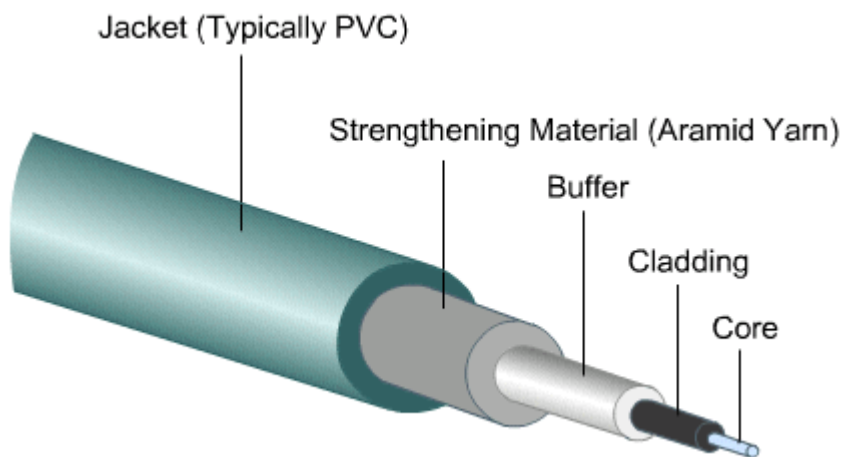
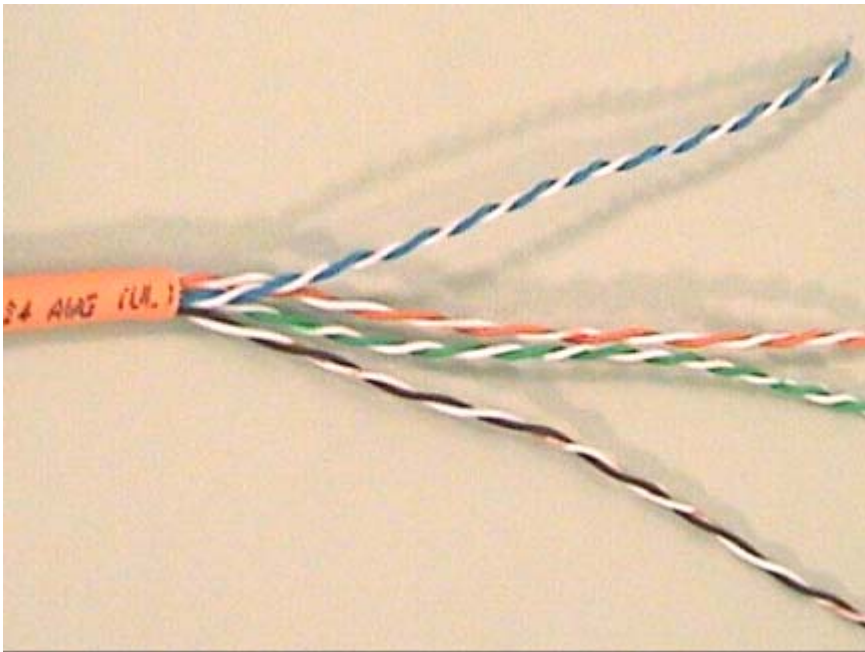
Course-level claim: Explain the issues associated with the transmission of signals on networking media.

Hands-on skills: Students should be able to use some basic cable test equipment.

4.2.1 Signals over copper and fiber optic cables

This is a review of Module 3 information. Using sample pieces of cabling, allow students to strip the cable back to see the construction of the cable.





4.2.2 Attenuation and insertion loss on copper media

Attenuation on cables is generally attributed to two factors. First, all waves lose energy to the medium in which they are traveling. Second, impedance mismatches are quite common. When looking into a window glass, there is an optical impedance mismatch and a reflection is seen. In audio systems, using cables that are not electrical impedance-matched results in poor signal transfer to the speakers. In coaxial systems, impedance mismatches caused by improperly terminated cables, not only cause attenuation by decreasing the signal, but also can form standing wave patterns on the cable. This can lead to unpredictable or completely faulty networking signals. Category 5e connectors and jacks are carefully engineered to minimize impedance mismatches. Impedance mismatches can result from poorly built cables.

4.2.3 Sources of noise on copper media

See prior discussion on the Faraday's law of induction and the origins of crosstalk in TI 4.1.7.

4.2.4 Types of crosstalk

Why does all this matter? Cabling has become more complex. Cables started with coaxial using a single central conductor and sheathing to UTP, with eight wires, twisted in four pairs. Data rates have increased. Copper versions of Ethernet have become 100 times faster from 10BASE-T to Gigabit Ethernet. People discovered that their physical medium and Layer 1 issues were getting more complex, especially more susceptible to noise and cabling defects. Cabling installations that worked fine at 10 Mbps sometimes had poor performance or simply failed to work at 1000 Mbps. To qualify cable to make sure it will work at the specified data rate, more and more tests are needed to assure the system will work are necessary.

Attention must be given to crosstalk or systems will fail. Students do not need to master the specific types of crosstalk. However, they should come to expect it as something that is normal and must be dealt with. For students, the basic messages are to keep the cable insulated, keep the wires as twisted as possible, and keep the wires in the correct order. The students should also look for damage to jacks and ports, and follow structured cabling practices.

The Attenuation-to-Crosstalk (ACR) graph is a key graph in preparing students for lessons 4.1 and 4.2. This is beyond the scope of the curriculum. To learn more visit Fluke's website at <http://www.flukenetworks.com/>.

4.2.5 Cable testing standards

One major distinction is that the ANSI/TIA/EIA-568-A cabling standards have been upgraded by the ANSI/TIA/EIA-568-B standards: B.1, B.2, B.3, and other addenda. These are wide ranging comprehensive copper and fiber standards. Consider having students do research on the cabling standards that apply in their locale.

The following are links to some structured cabling resources:

<http://www.flukenetworks.com/>

<http://www.linktionary.com/linktionary.html>

<http://www.ieee.org>

<http://www.siemon.com/us/>

<http://www.tiaonline.org>

<http://www.netday.org>

<http://www.iso.org/>

<http://www.panduit.com/>

4.2.6 Other test parameters

Remind students that an extensive list of tests must be passed before a cable is certified for Gigabit Ethernet.

4.2.7 Time-based parameters

The optional cable length lab from TI 4.2.9 could be done here as well. Students may ask about TDR since it is an abstract concept requiring a graphical explanation that is omitted from the current curriculum version. TDR, sometimes called cable radar, works in a similar way for both electrical and optical cables. The basic idea is to send out an electrical or optical pulse. The pulse is allowed to propagate down the cable. Here it may encounter different features such as discontinuities at connection or splice points or the end of the cable. Various designed features and undesirable features will act as discontinuities and cause some the incident pulse energy to be reflected. The reflections propagate back to the test device. Distance traveled equals rate multiplied by elapsed time. The rate times the elapsed time between when the pulse was sent and when the reflection is detected allows the distance to the cable feature or cable problem to be calculated.

4.2.8 Testing optical fiber

Again a local installer could be invited to demonstrate some of these tests. Refer back to TI 3.2.10. Have students check out Fluke Networks optical test equipment at <http://www.flukenetworks.com>.

4.2.9 A new standard

There are five labs in this TI with only one being required. Perform the required lab "Fluke 620 Cable Tester -- Wire Map", using available equipment. This lab is a good review of the cabling issues that have been discussed in Modules 3 and 4 and will raise student awareness of some very common wiring faults. The other four optional labs depend on the equipment and time available. Two of the four labs are more advanced use the Fluke 620 or equivalent. The last two labs use the new Fluke LinkRunner or equivalent. Even if the school does not have a LinkRunner, and most will not, students are encouraged to look at the features of this device at <http://www.flukenetworks.com/us/LAN/Handheld+Testers/LinkRunner/Overview.htm>. The features of the LinkRunner provide a good summary of the types of troubleshooting issues CCNAs will face in the workplace.

Module 4 Summary

Before moving on to Module 5, the students should be able perform basic cable quality tests. They should be familiar with basic terminology and equipment used in copper and optical cable testing. They should be able to give a qualitative description of how frequency-based cable testing relates to high speed LANs.

Online assessment options include the end-of-module online quiz in the curriculum and the online Module 4 exam. Consider having students answer some word problems that require use of the Flash calculators in the Module.

Students should understand the following main points:

- Waves are energy traveling from one place to another, and are created by disturbances. All waves have similar attributes such as amplitude, period, and frequency.
- Sine waves are periodic, continuously varying functions. Analog signals look like sine waves.
- Square waves are periodic functions whose values remain constant for a period of time and then change abruptly. Digital signals look like square waves.
- Exponents are used to represent very large or very small numbers. The base of a number raised to a positive exponent is equal to the base multiplied by itself exponent times. For example, $10^3 = 10 \times 10 \times 10 = 1000$.
- Logarithms are similar to exponents. A logarithm to the base of 10 of a number equals the exponent to which 10 would have to be raised in order to equal the number. For example, $\log_{10} 1000 = 3$ because $10^3 = 1000$.
- Decibels are measurements of a gain or loss in the power of a signal. Negative values represent losses and positive values represent gains.
- Time-domain analysis is the graphing of voltage or current with respect to time using an oscilloscope. Frequency-domain analysis is the graphing of voltage or power with respect to frequency using a spectrum analyzer.
- Undesirable signals in a communications system are called noise. Noise originates from other cables, RFI, and EMI. White noise affects all frequencies, while narrowband interference affects only a certain subset of frequencies.
- Analog bandwidth is the frequency range that is associated with certain analog transmission, such as television or FM radio.
- Digital bandwidth measures how much information can flow from one place to another in a given amount of time. Its units are in various multiples of bits per second.
- Most LAN problems occur at the physical layer. The only way to prevent or troubleshoot many of these problems is through the use of cable testers.
- Proper cable installation according to standards increases LAN reliability and performance.
- Copper media is available in shielded and unshielded forms. Unshielded cable is more susceptible to noise.
- Signal degradation is due to various factors such as noise, attenuation, impedance mismatch, and several types of crosstalk. These factors cause decreased network performance.

- The TIA/EIA-568-B standard specifies ten tests that a copper cable must pass if it will be used for modern, high-speed Ethernet LANs.
- Optical fiber must also be tested according to networking standards.
- Category 6 cable must meet more rigorous frequency testing standards than Category 5 cable.

Module 5: Cabling LANs and WANs

Overview

While teaching Module 5, keep in mind pacing and preparation. This module should be one of the highlights of the course. Students will apply what they have learned about networking terminology and media to the building of simple model LANs and WANs. Other than IP addressing, this is the core of the CCNA 1 experience.

Module 5 Caution

This is the most lab-intensive module in CCNA 1, requiring much preparation. PCs, cables (straight-through, crossover, rollover, serial DCE and DTE), hubs, switches, and routers are used in a series of Essential Labs. This is the module where students must master interconnecting Cisco networking devices. Particularly note that routers are now required to teach CCNA 1. Academies with high student-to-equipment ratios must schedule the flow through the labs carefully. Despite these challenges, students should not be deprived of these hands-on activities. They are crucial for concept and skill development. Depending on the Academy, this may be the only time the students ever cable up a network.

Students completing this module should be able to perform the following tasks:

- Identify characteristics of Ethernet networks
- Identify straight-through, crossover, and rollover cables
- Describe the function, advantages, and disadvantages of repeaters, hubs, bridges, switches, and wireless network components
- Describe the function of peer-to-peer networks
- Describe the function, advantages, and disadvantages of client-server networks
- Describe and differentiate between serial, Integrated Services Digital Network (ISDN), digital subscriber line (DSL), and cable modem WAN connections
- Identify router serial ports, cables, and connectors
- Identify and describe the placement of equipment used in various WAN configurations

5.1 Cabling LANs

Essential Labs: 5.1.5, 5.1.12, 5.1.13a, and 5.1.13b

Optional labs: 5.1.7 and 5.1.10

Core TIs: All

Optional TIs: none

Course-level claim: Describe the topologies and physical issues associated with cabling common LANs.

Hands-on skills: Students must be able to build small LANs using PCs, hubs, switches, and cables.

5.1.1 LAN physical layer

Note here that Ethernet is a family of technologies, which have some differences in both the physical and data link layers, including media. Token Ring and FDDI are mentioned only as LAN comparisons for Ethernet.

5.1.2 Ethernet in the campus

Explain that the statement, “10 Mbps gives good performance” is no longer accurate. It was not that long ago that a 20 MB hard drive was huge and 64 MB of RAM helped software run quickly. Stress that performance depends on what applications are being used, what tasks are being performed, and the expectations of the users.

5.1.3 Ethernet media and connector requirements

Students do not need to memorize the chart. It is basically a preview of Module 7. Do call attention to the fact that the different types of Ethernet, all IEEE 802.3 LAN technologies, use different media, have different connectors, and have different distance limitations.

5.1.4 Connection media

Pass hubs, switches, routers around, or take students to the rack in the class and call attention to the kinds of connections on each device. Differentiate for the students what connections are typically for LANs and which are WANs.

5.1.5 UTP implementation

Build upon knowledge gained in making cables in TI 3.1.9. It is crucial that students can physically identify cables and use them for the correct purpose. Again build a network with all three kinds of UTP. If possible, run a drop within the classroom that connects a lab PC to the equipment and terminates at a faceplate. A mock wall is also a great tool. After the initial investment, it requires minimal funds to get two new pieces of drywall and replace it each semester.

The lab is required. It is crucial that students understand end-to-end physical connection issues. This also builds skills useful for punching down cables in patch panels. Reinforce the necessity of quality punch-downs or else the noise issues discussed in Module 4 will arise.

At this point instructors should consider the required structured cabling case study and installation project. However the timing and format are completely up to the local instructors. At this point in the course the students will have covered some of the basic skills.

Additional cabling opportunities should be considered. More on the case study is presented in the Case Study appendix, after Module 11.

5.1.6 Repeaters

Ask the IT department for a tour of the school and point out the various devices in RIOs 5.1.6 through 5.1.10. Make sure to also point out the routers. The ability to draw networking symbols should be reinforced to the students. In terms of the OSI model, repeaters are Layer 1 devices. In terms of PDUs, repeaters process bits according to the algorithm. Repeaters repeat any signals detected on the incoming port to the outgoing port. Consider kinesthetic activities and role-plays to act out the device algorithms, starting with the repeater.

5.1.7 Hubs

Using a hub, hook up a number of PCs and generate significant traffic. Time how long it takes to transfer a big file with few hosts attached, and then simultaneously with a lot of hosts attached. Circulate hubs for examination by students. Explain hubs as multiport repeaters. Again, the ability to draw networking symbols should be reinforced to the students. The lab "Hub and NIC purchase" is optional. In terms of the OSI model, hubs are Layer 1 devices. In terms of PDUs, hubs process bits according to the algorithm. Hubs repeat any signals detected on the incoming port to all ports except that incoming port. The students could flowchart a simplistic view of the device algorithm. Consider kinesthetic activities and role-plays to act out the device algorithms, continuing with the hub.

5.1.8 Wireless

Circulate any wireless devices available for examination by students. Wireless networks are rapidly becoming ever-present as wired LAN extensions.

5.1.9 Bridges

The ability to draw networking symbols should be reinforced to the students. In terms of the OSI model, bridges are Layer 2 devices. Note that all Layer 2 devices must also function at Layer 1. Take time here to stress bridge logic, this will be revisited in Module 8. In terms of PDUs, bridges process frames according to the algorithm. Bridges forward non-local and unknown traffic where non-local traffic is defined by MAC addresses. Bridges also forward all Layer 2 broadcasts, but do not forward frames with local MAC addresses. The students could flowchart a simplistic view of the device algorithm. Consider kinesthetic activities and role-plays to act out the device algorithms, continuing with the bridge.

5.1.10 Switches

Consider repeating the hub demonstration in TI 5.1.7 using a switch. Show how the file transfer time decreases. Explain switches as multiport bridges. The ability to draw networking symbols should be reinforced to the students. In terms of the OSI model, switches are Layer 2 devices. Note that all Layer 2 devices must also function at Layer 1. Take time here to stress bridge logic, this will be revisited in Module 8. In terms of PDUs, switches process frames according to the bridging algorithm applied to the switch ports. This process is called microsegmentation. The students could flowchart a simplistic view of the device algorithm. Consider kinesthetic activities and role-plays to act out the device algorithms, continuing with the switch. The lab "Purchasing LAN switches" is optional but useful for getting students to explore the real world of switching.

5.1.11 Host connectivity

Reinforce the importance of using the correct NIC and proper installation. In terms of the OSI model, NICs are Layer 2 devices. Note that all Layer 2 devices must also function at Layer 1.

5.1.12 Peer-to-peer

A relevant TI from CCNA 1 v2.1.4 is 2.2.5. Consider configuring two or three workstations and set up peer-to-peer networking demonstration using Windows software. The lab "Building a Peer-to-Peer Network" is required. It is the first key step in a series of network building labs allowing students to master device interconnection. These and subsequent network building labs are crucial skills for the WWE, ILSG, and industry definitions of CCNA. The networking building labs are crucial for the cognitive and affective growth of the student in the domain of networking.

5.1.13 Client-server

This is another area to call on external sources. The IT department may donate some time to talk to the students about the school network and the client-server relationships.

The labs "Building a Hub-based Network" and "Building a Switch-based network" are required. Instructors are, as always, free to combine and time the labs to best serve their students.

5.2 Cabling WANs

Essential Labs: 5.2.3a, 5.2.3b, 5.2.3c, and 5.2.7

Optional labs: none

Core TIs: 5.2.1, 5.2.2, 5.2.3, and 5.2.7

Optional TIs: 5.2.4, 5.2.5, and 5.2.6

Course-level claim: Describe the physical issues associated with cabling networking equipment to work over a WAN link.

Hands-on skills: Students must be able to build small LANs and WANs using PCs, hubs, switches, routers, and cables. Students must also be able to establish console connections to devices. Students must be able to perform simple troubleshooting of Layer 1 issues in these small model LANs and WANs.

5.2.1 WAN physical layer

Have students begin to compare and contrast LAN standards and connections and WAN standards and connections. This is a preview of CCNA 4.

5.2.2 WAN serial connections

This is an important building block in student understanding of connectivity and limitations. Spend adequate time on Figure 2. Hand out examples of modems, modem cables, and serial cables for students to examine. Highlight the DCE and DTE distinction. Explain to students that they will not be working with a CSU/DSU and will instead connect the DCE cable directly to the DTE cable. If a CSU/DSU is available, demonstrate how the serial connections would actually be performed.

5.2.3 Routers and serial connections

This is an extremely important TI with far too much material in it. This may be a good place to start emphasizing to students that routers connect networks. Routers allow the creation of networks of networks, or an internetwork. In the late 1990s as Internet usage increased rapidly, "internetwork" was a term to emphasize the distinction from LANs. Now the word network is used almost universally and is considered to include routers, routing, WANs, and internetworking.

Draw some router topologies on the board and ask how many networks there are, and which are LANs, and which are WANs. This establishes the purpose of routers and shows the interfaces on them with the required cabling. If possible, hand out routers. Explain the physical identification of DCE and DTE cables in terms of markings on cables and in terms of pinouts or gender on the connectors.

The Essential Labs "Connecting Router LAN Interfaces", "Building a Basic Routed WAN", and "Troubleshooting Interconnected devices" are three of the most important labs in this course. Here students are learning to build the CCNA 2 two-router topology.

Students will make mistakes as they build the networks. In this section of the four-semester curriculum, cabling mistakes are allowable. Troubleshooting can be difficult to learn and will take a lot of practice. Help students with the troubleshooting. Explain that troubleshooting involves searching for clues, being logical, and documenting everything. Have the students determine what does and does not work. Documenting this and what has been tried should be encouraged.

Students have only have a few troubleshooting tools available at this point, but they should understand how to use them successfully. Link lights and pings are their basic tools here. When something is broken, students are inclined to ping all over the place in a non-sequential manner. This wastes time and does not focus in on the problem. Explain that if something does not work, pinging should be done to the closest interface first. If it works, ping the next closest interface and continue to ping the next, increasingly distant, interface. Eventually, one will fail, and the problem has been narrowed in scope. Also explain that there may be multiple problems. Find and fix one at a time, and then find and fix the next, until everything works properly.

To ping a router, it must be configured. However, router configuration is not a CCNA 1 topic. Have configurations on the router that will allow students to bring up the interfaces and run RIP.

5.2.4 Routers and ISDN BRI connections

This is to increase student awareness that not all connections, connectors, and jacks are alike. Depending on the locale, students may have seen ISDN home connections.

5.2.5 Routers and DSL connections

This is to increase student awareness that not all connections, connectors, and jacks are alike. Depending on the locale, students may have seen DSL home connections.

5.2.6 Routers and cable connections

This is to increase student awareness that not all connections, connectors, and jacks are alike. Depending on the locale, students may have seen cable modem home connections.

5.2.7 Setting up console connections

The lab "Establishing a Console Connection to a Router or Switch" is required. This lab builds upon the earlier labs where students made console cables and it is a preparation for CCNA 2.

Module 5 summary

Before moving on to Module 6, the students must be proficient in cabling networks. Remind the students that they have just built several small LANs and a model, simulated WAN.

Online assessment options include the end-of-module online quiz in the curriculum and the online Module 5 exam. Develop a type of skills-based quiz, or exam, to strengthen the capability of the students to efficiently cable a network. Students must master this skill at this point in the curriculum.

Students should understand the following main points:

- A network interface card (NIC) provides network communication capabilities to and from a PC.
- Use a crossover cable to connect between two similar devices, such as switches, routers, PCs, and hubs.
- Use a straight-through cable to connect between different devices, such as connections between a switch and a router, a switch and a PC, or a hub and a router.
- There are two major types of LANs, peer-to-peer and client/server.
- WANs use serial data transmission. WAN connection types include ISDN, DSL, and cable modems.
- A router is usually the DTE and needs a serial cable to connect to a DCE device like a CSU/DSU.
- The ISDN BRI has two types of interfaces, S/T and U interfaces. To interconnect the ISDN BRI port to the service-provider device, a UTP Category 5 straight-through cable with RJ-45 connectors, is used.
- A phone cable and an RJ-11 connector are used to connect a router for DSL service.
- Coaxial cable and a BNC connector are used to connect a router for cable service.
- A rollover cable is used to connect a terminal and the console port of an internetworking device.

Module 6: Ethernet Fundamentals

Overview

While teaching Module 6, emphasize two graphical representations. First, repeatedly contrast the Ethernet Layers with the OSI model. Second, repeatedly call attention to the IEEE 802.3 Ethernet frame structure.

Module 6 Caution

Several of the major concepts, especially the timing, interframe spacing, backoff, duplex, and auto-negotiation, are abstract and difficult to master. Unfortunately this difficulty is compounded by a relative lack of graphics. Upcoming instructional materials will address this, but for now consider drawing diagrams to help students visualize the concepts in this module.

Students completing this module should be able to perform the following tasks:

- Describe the basics of Ethernet technology
- Explain naming rules of Ethernet technology
- Define how Ethernet and the OSI model interact
- Describe the Ethernet framing process and frame structure
- List Ethernet frame field names and purposes
- Identify the characteristics of CSMA/CD
- Describe the key aspects of Ethernet timing, interframe spacing, and backoff time after a collision
- Define Ethernet errors and collisions
- Explain the concept of auto-negotiation in relation to speed and duplex

6.1 Ethernet Fundamentals

Essential Labs: none

Optional labs: none

Core TIs: all

Optional TIs: none

Certification-level claim: Compare and contrast key characteristics of LAN environments.

Course-level claim: Explain the fundamental concepts associated with the Ethernet media access technique.

Hands-on skills: none

6.1.1 Introduction to Ethernet

This TI is presented mostly for contextual reasons. However, the analogy of the Hawaiian Islands as “stations” with the atmosphere as the shared medium can be compared to Ethernet NIC “stations” on the shared coaxial medium. It may be a good idea to discuss the origin of the term Ethernet. The story is concisely told in <http://www.ethermanage.com/ethernet/ethersname.html>.

6.1.2 IEEE Ethernet naming rules

This TI relates to TIs 2.1.3, 2.1.4, 3.1.6, 3.1.9, 4.2.5, 4.2.9, and 5.1.1 through 5.1.13. Therefore, the students should already have a fair amount of exposure to Ethernet and build upon that prior knowledge. Use Modules 6 and 7 to build to mastery. This TI expands upon the naming conventions introduced earlier in the course. Have students consult their engineering journals to verify notes and expand on the explanation.

Note: It is important to instill in the students the need for complete and accurate documentation. Instructors should also keep an engineering journal and use it in the classroom. Have all students visit Charles Spurgeon's Ethernet site <http://www.ethermanage.com/ethernet/ethernet.html>.

6.1.3 Ethernet and the OSI model

Explain that each layer in the source does not just talk to the corresponding layer in the destination straight across. All traffic goes down to the physical layer in the source, then across the medium. It is processed by any intermediate networking devices, and then travels up through the layers in the destination.

Figure 1 can be confusing. The physical medium is not another layer in the OSI model. Technically it exists outside of the OSI model. OSI Layer 1 actually deals with the specifics of how the NIC interfaces to the physical medium, connectors and signals. So IEEE specifications govern OSI Layer 2, OSI Layer 1, and the actual physical medium that is outside the OSI model.

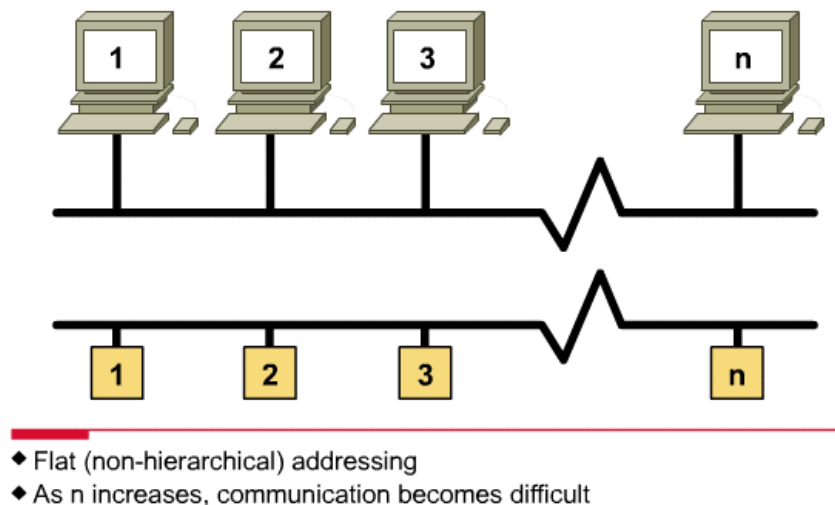
Figure 5 requires careful examination. In order to have a common interface between the different LAN technologies and the network layer, IEEE specifies the logical link control (LLC). This part of Layer 2 is common to all the IEEE LAN and MAN specifications. Then there are the physical layer details at OSI Layer 1 and physical medium detail.

6.1.4 Naming

Consider an activity where the students gather manufacturer names and identifiers. Discuss what worldwide organization assures the uniqueness of MAC addresses. Students may find additional relevant information in Radia Perlman's book, "Interconnections, Second Edition: Bridges, Routers, Switches, and Internetworking Protocols", 1999, Addison-Wesley, [ISBN 0201634481](https://www.addison-wesley.com/ISBN/0201634481). The book includes a discussion of the naming of computers on a LAN.

As a thought experiment, have students imagine a LAN where only MAC addresses are used. Talk about the strengths, such as simplicity of addressing. Then discuss the weaknesses, such as how a flat addressing scheme does not scale well as the number of stations increases. Refer back to LO 1.2 when students were introduced to hexadecimal numbers. Explain that MAC addresses as flat addressing space are similar to social security numbers.

MAC Addresses: A Flat Addressing Scheme



6.1.5 Layer 2 framing

This is an extremely important TI in terms of cognitive development and concept building. Streams of OSI Layer 1 PDUs, bits, need structure, so OSI Layer 2 frames are used. The generic frame is introduced to underscore that not all frames are Ethernet, but all frames typically need similar information to perform their functions on a LAN. Remind the students of the communications system lab 3.1.9a, as student may have invented some crude framing structures.

Three Analogies for Data Frames

- ♦ A picture frame marks the borders of a painting;

A data frame shows the borders of encapsulated data

- ♦ A shrink-wrapped pallet is the last step before heavy objects are shipped;

Framing is the last packaging before data is transmitted on the medium

- ♦ Video is conveyed as a series of still images called frames;

Data (information) is conveyed as a series of data frames

6.1.6 Ethernet frame structure

Ethernet can mean 10, 100, 1000, or 10,000 Mbps. It can mean thick or thin coaxial cable, UTP cable, or multimode or single-mode fiber. The one thing common to all forms of Ethernet is the frame structure. This is what allows the interoperability of the different types of Ethernet.

6.1.7 Ethernet frame fields

Explain the difference between the two frames briefly, then just focus on the 802.3 frame. It is crucial for students to study this frame carefully. Anticipating future lessons, use the Ethernet frame, the IP packet, and the TCP segment, as graphical representations across all four semesters of CCNA curriculum.

6.2 Ethernet Operation:

Essential Labs: none

Optional labs: none

Core TIs: 6.2.1, 6.2.2, 6.2.9, and 6.2.10

Optional TIs: 6.2.3, 6.2.4, 6.2.5, 6.2.6, 6.2.7, and 6.2.8

Certification-level claim: Compare and contrast key characteristics of LAN environments.

Course-level claim: Explain how collisions are detected, and the concepts associated with auto negotiation on an Ethernet system.

Hands-on skills: none

6.2.1 MAC

There are a variety of entertaining activities comparing Token Ring media access rules with Ethernet. Have students write notes to each other, and form a circle. Make a “talking stick”, or token. As the token is passed, if a student has a message to send they can if they have the token. One message is sent at a time.

This demonstration illustrates how collisions work on the Ethernet. The “message” cannot get out do to interference or the inability to pass on the note.

Three Analogies for Media Access Control

- ♦ Stopping at a tollbooth
- ♦ Waiting in a ticket line
- ♦ Speaking in a meeting

6.2.2 MAC rules and collision detection/backoff

Discuss collision domains. Draw different topologies on the whiteboard. Have students identify the number of networks, the number of LANs, the number of WANs, and now the number of collision domains. Reinforce which devices create new collision domains. Sometimes it is difficult to realize that more, smaller collision domains are better than one large collision domain. Consider a kinesthetic activity or role-play, acting out the CSMA/CD algorithm.

6.2.3 Ethernet timing

This TI should include this simple formula: $1/\text{bandwidth} = \text{bit time}$, but it does not. For example $1/10,000,000 \text{ bits/second} = .000001 \text{ second/per bit}$ for 10Mbps Ethernet. This relationship is really the most important aspect of this TI. The concept of slot time is necessary to account for physical size of network and propagation time. It may help to convert some of this text-laden TI into timing diagrams to help students with this material. Additional instructional materials will be created.

6.2.4 Interframe spacing and backoff

It may help to convert some of this text-laden TI into timing diagrams to help students with this material. Additional instructor materials will be created.

6.2.5 Error handling

Collisions are a natural part of functioning of Ethernet. It is excessive collisions that are the problem. Most collisions in modern Ethernets are now avoided by use of full duplex connections. Collisions and the techniques and devices used to manage them are important parts of understanding Ethernet.

6.2.6 Types of collisions

This TI provides a good review of the Ethernet frame. Physical signal collisions are possible on 10BASE5 and 10BASE2 networks. They are also possible within some 10BASE-T hubs that act like a bus topology internally. However, most copper Ethernet technology will use separate transmit and receive wire pairs within the UTP. In these cases, collisions are defined as simultaneous activity on the transmit and receive circuits. Full duplex settings override this. Full duplex is the operating mode for most new Ethernet installations.

6.2.7 Ethernet errors

This TI introduces some terminology. However, the key point here is although most of the time Ethernet works well, these are real symptoms.

6.2.8 FCS and beyond

Take time to review the concept of FCS as a packing slip. Consider a kinesthetic activity or role-play. This and the next TI can be a bit overwhelming. It is important that FCS and minimum/maximum frame sizes be understood.

6.2.9 Ethernet auto-negotiation

The introduction of this somewhat abstract topic, even in the first course, can help students start to begin to understand Ethernet speed and duplex issues. There are several points to emphasize when teaching this TI. First, networks are alive with signals. Fast Link Pulses (FLPs) are an example of how the network uses pulses to make synchronization of a variety of different speeds of Ethernet possible. Finally, auto-negotiation problems are extremely common.

6.2.10 Link establishment and full and half duplex

Note that in full duplex, 10BASE-T can carry 20Mbps of user data plus overhead. Likewise full duplex 100BASE-TX can transmit 200 Mbps. However, full duplex 1000BASE-T can only transmit up to 1000Mbps, because it is already using full duplex on each wire pair simultaneously. This results in permanent collisions that are decoded by sophisticated interface circuitry. Despite the historical and conceptual importance of CSMA/CD, Ethernet connections today are switched full duplex connections, which act as point-to-point links.

Module 6 Summary

Before moving on to Module 7, the students should know the Ethernet frame by memory and be able to decode the Ethernet naming conventions. The student should be able to use a wide range of Ethernet-related vocabulary to describe collisions, errors, and auto-negotiation on modern Ethernet LANs.

Online assessment options include the end-of-module online quiz in the curriculum and the online Module 6 exam. Consider having students draw their understanding of the CSMA/CD and auto-negotiation flowcharts. Given an unlabeled Ethernet frame diagram, students should be able to add in the names, numbers of bytes, and brief explanations of the Ethernet frame fields.

Students should understand the following main points:

- The basics of Ethernet technology
- The naming rules of Ethernet technology
- How Ethernet and the OSI model interact
- Ethernet framing process and frame structure
- Ethernet frame field names and purposes
- The characteristics and function of CSMA/CD
- Ethernet timing
- Interframe spacing
- The backoff algorithm and time after a collision
- Ethernet errors and collisions
- Auto-negotiation in relation to speed and duplex

Module 7: Ethernet Technologies

Overview

Convey to the students how Ethernet technology has increased in speed from 10 Mbps to 10,000 Mbps in less than a decade. Emphasize that the frame structure on all Ethernet speeds have the same frame characteristics. This leads to excellent interoperability on 10/100/1000 Ethernet interfaces.

Note: Most Ethernet copper connections are switched full duplex and the fastest copper-based Ethernet is 1000BASE-T.

Ethernet at speeds of 10-Gigabit and faster are exclusively optical fiber-based technologies. There are basic considerations that help drive the architectural rules of Ethernet. Examples are the 100-meter rule for copper and the tradeoff that exists between distance and bandwidth in fiber.

Module 7 Caution

The introduction of the facts and terminology in this module can easily overwhelm the students. The encoding schemes presented in the curriculum detail important characteristics on the different Ethernet varieties. The complexity surpasses what is needed for certification. Therefore, the material presented is useful as background information. The Protocol and Network Analysis software are powerful but complex tools. To use such powerful tools without confusing students in an introductory course requires a significant amount of preparation by the instructor.

Students completing this module should be able to perform the following tasks:

- Compare and contrast 10BASE5, 10BASE2, and 10BASE-T Ethernet technology
- Define Manchester encoding
- List the factors affecting Ethernet timing limits
- List 10BASE-T wiring parameters
- Describe the key characteristics and varieties of 100-Mbps Ethernet
- Describe the evolution of Ethernet
- Explain the MAC methods, frame formats, and transmission process of Gigabit Ethernet
- Describe the uses of specific media and encoding with Gigabit Ethernet
- Identify the pinouts and wiring typical to the various implementations of Gigabit Ethernet
- Compare and contrast Gigabit and 10-Gigabit Ethernet
- Describe the basic architectural considerations of Gigabit and 10-Gigabit Ethernet

7.1 10-Mbps and 100-Mbps Ethernet

Essential Labs: 7.1.2, 7.1.9a, and 7.1.9b

Optional labs: none

Core TIs: 7.1.1, 7.1.4, 7.1.5, 7.1.6, 7.1.7, and 7.1.9

Optional TIs: 7.1.2, 7.1.3, 7.1.8, and all TIs that refer to encoding

Certification-level claim: Compare and contrast Gigabit and 10-Gigabit Ethernet.

Course-level claim: Describe the structure and technologies used in networking systems. Describe networking topologies and the physical issues associated with cabling common LANs.

Hands-on skills: Students should be able to decode a simple Ethernet waveform, and describe the use, at a very simple level, of network analysis and protocol sniffing software.

7.1.1 10-Mbps Ethernet

Review the standards displayed in Figure 1 with the students. As faster versions of Ethernet are introduced throughout the course, the students should refer back to Figure 2 to have a better understanding of the media. Two points to emphasize are that all 10-Mbps forms of Ethernet share the same frame structure, timing parameters, and Manchester encoding. Also, the SQE pulses are another example of the statement "networks are alive".

Practice problem

Given that 10-Mbps Ethernet sends one bit every 100 nanosecond, calculate the time it takes to send a 1518 byte frame.

$1518 \text{ bytes} \times 8 = 12144 \text{ bits}$

$12144 \times 100 \times 10^{-9} = 0.0012144 \text{ seconds}$

7.1.2 10BASE5

10BASE5 is included for historical reasons but is rarely implemented today. Explain to the students that a signal representing Manchester encoding on an oscilloscope would not be represented by binary ones or zeros. For example, when looking at ASCII code in binary, an 'a' would be represented by ASCII decimal 97 which would equal binary digits 01100001. A 'p' would represent ASCII decimal 112 which would equal binary digits 01110000. Decoders are needed to translate the code or waves in a form that is understood.

Lab 7.1.2 "Waveform Decoding" is required. However, instructors have academic freedom on how much of the lab materials are presented. The Waveform Decoding lab activity covers TIs 7.1.2 through 7.1.7. This lab activity is challenging but engaging. It integrates the OSI model, the encapsulation process, the Ethernet frame format, and encoding methods.

Note: A PDF of the waveform for the students to complete is available to instructors.

7.1.3 10BASE2

10BASE2 has been included primarily for historical reasons, to help students see the evolution of Ethernet. The waveform in the "Waveform Decoding" lab in 7.1.2 was captured off a 10BASE2 network.

7.1.4 10BASE-T

This is a repeat of information in 7.1.1 and is a good time to reinforce half and full duplex definitions. 10BASE-T is the technology that stimulated the exponential growth of Ethernet LANs in the mid-1990s. 10BASE-T helped establish Ethernet as the dominant LAN technology over Token Ring, FDDI, ATM LANE, and other LAN technologies. However, current trends do not include 10BASE-T installed end-to-end. Most NICs for PCs are 10/100, as are an increasing number of switch ports and router interfaces.

7.1.5 10BASE-T wiring and architecture

Review the limitations of specific architectures, particularly the use of devices that extend the LAN.

Note: With the introduction of switches, the four-repeater, or hub, rule is not relevant.

The LAN can be extended indefinitely by daisy chaining switches. Each switch-to-switch connection, with maximum length of 100 m, is essentially a point-to-point connection without the media contention or timing issues of using repeaters and hubs. However, past a certain number of interconnected switches, the network becomes very inefficient and routers must be used.

7.1.6 100-Mbps Ethernet

This TI has two key points. First, all forms of Fast Ethernet share the same frame format and timing information. One major difference from 10-Mbps Ethernet is timing, with one Fast Ethernet bit occurring in one-tenth of the time of 10 Mbps. Consider drawing a timing diagram showing two successive 10-Mbps streams and two successive 100-Mbps streams on the same time scale. Note that signals occurring in less time become more susceptible to noise. So an encoding scheme even more complex than Manchester was used.

The specifics of encoding are not important. An important design detail is a ten-fold increase in the speed or bandwidth, which requires careful consideration. 100 Mbps forms of Ethernet can transmit 200 Mbps in full duplex. UTP has separate transmit and receive wire pairs, and most optical fiber cables have separate transmit and receive fiber.

Practice problem Fast Ethernet

1 bit every 10 nanosecond

Calculate the time it takes to send a 1518 byte frame.

$1518 \text{ bytes} \times 8 = 12144 \text{ bits}$

$12144 \times 10 \times 10^{-9} = 0.00012144 \text{ seconds}$

7.1.7 100BASE-TX

100BASE-TX uses same wiring as 10BASE-T. Although this information is not relevant to the course, careful observation reveals that Multi-Level Transmit (MLT-3) encoding uses three voltage levels to signal binary ones and zeros. It does this in order to achieve desirable signal-to-noise and bandwidth characteristics. 100BASE-TX is the standard desktop LAN connection in many organizations.

7.1.8 100BASE-FX

The main point of including 100BASE-FX is for its comparison to 100BASE-TX. The technology was never really accepted. Gigabit Ethernet was quickly developed and 1000BASE-T over Category 5e allowed instant interoperability with existing copper systems using 10/100/1000 interfaces.

Therefore, Gigabit Ethernet and not 100BASE-FX became the dominant wiring closet technology. 100BASE-FX encoding on the optical fiber is actually quite simple, using bright light or dim light for 1s or 0s.

7.1.9 Fast Ethernet architecture

Most of the chart details are for reference purposes. It is important to compare copper distances with fiber distances for the same speed of technology. Also note that there are a variety of architectural rules.

The most important aspects of this TI are the Essential Labs, “Introduction to Fluke Network Inspector” and “Introduction to Fluke Protocol Inspector”. An introduction to these programs also occurs at the end of lab 7.1.2. The Fluke software is not required, and any network analysis and protocol analysis software are acceptable. The frame capture view in protocol analysis software shows a network is alive with PDUs, even when no traffic is flowing. Also, the network is filled with conversations when transactions such as HTTP and DNS occur. Instructor opinions will certainly vary, but there is great benefit to students if a well-explained frame capture is presented.

Endless extensions of these labs can be done throughout the four CCNA semesters. Experience has shown that students need substantial guidance when using these tools. Class demonstrations are vital.

7.2 Gigabit and 10-Gigabit Ethernet

Essential Labs: none

Optional labs: none

Core TIs: 7.2.1, 7.2.2, 7.2.3, and 7.2.7

Optional TIs: 7.2.4, 7.2.5, and 7.2.6

Certification-level claim: Compare and contrast key characteristics of the LAN environment

Course-level claims: Define and describe the structure and technologies of computer networks. Describe the topologies and physical issues associated with cabling common LANs.

Hands-on skills: none

7.2.1 1000-Mbps Ethernet

Repeat the calculations from 7.1.6 with Gigabit Ethernet. One major difference from 10-Mbps and 1000-Mbps Ethernet is the timing. One Gigabit Ethernet bit occurs in 1/10 of the time of 100 Mbps and 1/100 of the time of 10 Mbps. Consider drawing a timing diagram showing two successive 10-Mbps bits, 100-Mbps bits, and 1000-Mbps bits on the same time scale. Note that with signals occurring in less time the bits become more susceptible to noise. An encoding scheme even more complex than Manchester and MLT-3 is used.

Practice problem Gigabit Ethernet

One bit every 1 nanosecond

Calculate the time it takes to send a 1518 byte frame.

$$1518 \text{ bytes} \times 8 = 12144 \text{ bits}$$

$$12144 \times 1 \times 10^{-9} = 0.000012144 \text{ seconds}$$

7.2.2 1000BASE-T

Students may inquire as to how 1000 Mbps was achieved. When using Category 5e UTP, there are basic bandwidth limitations and attenuation due to crosstalk ratios at high signal frequencies. The NIC or interface has to be able to change voltage level signaling bits on copper and still be detected reliably 100 meters away, at the receiving NIC or interface.

The demand for Ethernet grew faster than 100 Mbps. Engineers did the following three things to extend past Fast Ethernet over copper:

- 1) Using Category 5e UTP cable and careful improvements in electronics, the signal was boosted from 100 Mbps per wire pair to 125 Mbps per wire pair.
- 2) Instead of using only two-wire pairs, use all four-wire pairs. 10BASE-T and 100BASE-TX only used two-wire pairs while the others lay in the cable unused. This would allow 125 Mbps per wire pair or 500 Mbps on four-wire pairs in UTP combined.
- 3) By using very sophisticated electronics, it allowed permanent collisions on each wire pair and ran signals in full duplex. This doubled the 500 Mbps to 1000 Mbps. The 100-meter distance limitation still applies.

The advantages of 1000BASE-T include:

- a) It will run over existing Category 5 cable plants that have been recertified as Category 5e.
- b) It is interoperable with 10BASE-T and 100BASE-TX. 10/100/1000 NICs and interfaces are becoming more common.

Interoperability and adaptability makes 1000BASE-T the technology of choice for installation in the wiring closet and to the workstation.

7.2.3 1000BASE-SX and LX

Figure 2 shows how the different forms of Gigabit Ethernet vary. SX stands for the short infrared wavelength of 870 nm. LX stands for the long infrared wavelength. LX has a range of 1300 nm in fiber without unacceptable distortion of the bits. Refer students back to the spectrum chart. If these two wavelengths were in the visible spectrum of 400 to 700 nm, they would be seen in different colors. Instead they are in infrared.

Figure 1 shows the primary advantages of the fiber versions of Gigabit Ethernet. These advantages include relative noise immunity, small size, and increased unrepeat distances and bandwidth. The simpler and cheaper LED or laser/multimode system of 1000BASE-SX makes it useful for backbone, vertical, and longer LAN cabling runs. 1000BASE-LX has a distance of up to 5000m (5 km) unrepeat across a large campus. 1000BASE-CX is an uncommon media meant for high-data rate transfers in a high-noise environment that uses copper. Fiber or UTP variants are what are used today.

7.2.4 Gigabit Ethernet architecture

Fiber modal bandwidth is measured in MHz-Km. This is the maximum distance a signal can travel in fiber without the signal becoming distorted. This dispersion is due in part because different light modes traveling down the fiber will take different paths. However, the rays of light have different times of travel that potentially creates a problem on the receiving end. Modal bandwidth is not applicable for single mode fiber since the multimode problem does not exist. However, single mode also has ultimate distance and bandwidth limitations. There really is no point to running Gigabit Ethernet in half duplex. However, for historical reasons it was left in the standards.

7.2.5 10-Gigabit Ethernet

One major difference in going from 1000-Mbps (Gigabit) Ethernet to 10,000-Mbps Ethernet (10-Gigabit Ethernet) is the basic system timing. A 10-Gigabit Ethernet bit occurs in 1/10 of the time of a Gigabit Ethernet bit, 1/100 of the time of Fast Ethernet bits, and 1/1000 of the time of 10-Mbps bits. Consider drawing a timing diagram showing two successive 10-Mbps bits, 100-Mbps bits, 1000-Mbps bits, and 10,000-Mbps bits on the same time scale. The bits become more susceptible to noise as the signals decrease with time. Therefore, the encoding scheme grows even more complex. The key point is that the Ethernet frame retains its form, even though it is running 1000 times faster than legacy Ethernet. Students do not need to worry about all of the different 10GBASE designations. They do need to be aware that Ethernet is now dealing with MAN and WAN distances at super LAN speeds.

Practice problem 10-Gigabit Ethernet

one bit every 0.1 nsec

Calculate the time it takes to send a 1518 byte frame.

$$1518 \text{ bytes} \times 8 = 12144 \text{ bits}$$

$$12144 \times .1 \times 10^{-9} = 0.0000012144 \text{ seconds}$$

7.2.6 10-Gigabit Ethernet architectures

In Figure 1, a unique version of 10-Gigabit Ethernet uses wavelength division multiplexing over optical fiber to achieve amazing data rates. The key device here is a tiny prism. Prisms bend light, including infrared, at different angles, depending on color. Four colors of light, or wavelengths, are multiplexed on to one fiber. The combination of four slightly different laser beams by a prism makes up one fiber beam. A prism at the other end of the cable separates the four colors into different detectors. Data is split up into streams for parallel transmission where each stream is one of four laser beams. Figure 2 shows that there are strict architecture rules for 10-Gigabit Ethernet. It is not clear at this time which of these technologies will dominate the marketplace. Students should know that 10-Gigabit Ethernet exists and appreciate its speed relative to other Ethernet technologies. Note, however, that it can only be achieved using optic fiber and continuous research is on-going in this technology.

7.2.7 Future of Ethernet

Discuss what makes all of these different technologies Ethernet. The main reasons are the frame format, the historical evolution, and the IEEE specification. Most other details vary widely. Ethernet dominates LANs already, but now it is also making entries into traditionally MAN and WAN applications. The demand for Ethernet will determine which varieties will survive and thrive. CSMA/CD is crucial to understanding how Ethernet evolved. However, Ethernet, for the most part, is now full duplex point-to-point switched connections not running under CSMA/CD.

Module 7 Summary

Before moving on to Module 8, the students must be proficient in comparing and contrasting the major features of Legacy, Fast, Gigabit, and 10-Gigabit Ethernet.

Online assessment options include the Module 7 Quiz in the curriculum and the Module 7 exam. Have the students draw a concept map for Ethernet and note how the various technologies are grouped.

Students should understand the following main points:

- The differences and similarities among 10BASE5, 10BASE2, and 10BASE-T Ethernet
- Manchester encoding
- The factors affecting Ethernet timing limits
- 10BASE-T wiring parameters
- The varieties of 100-Mbps Ethernet and its key characteristics
- The evolution of Ethernet
- MAC methods, frame formats, and transmission process of Gigabit Ethernet
- The uses of specific media and encoding with Gigabit Ethernet
- The pinouts and wiring typical to the various implementations of Gigabit Ethernet
- The similarities and differences between Gigabit and 10-Gigabit Ethernet
- The basic architectural considerations of Gigabit and 10-Gigabit Ethernet

Module 8: Ethernet Switching

Overview

When teaching Module 8, remind students of the evolution of networking devices from repeaters and hubs through bridges and switches. Discuss the real world aspect emphasizing the importance of switching in LANs used today. An upcoming instructional resource on CAC called Packet Tracer will be useful in teaching this module. Consider introducing the concept of VLANs at this point. It is relevant to the discussion of network segmentation in collision and broadcast domains.

Module 8 Caution

The concepts of bridging and switching are difficult for students to understand. Identifying collision domains and broadcast domains requires practice. The theory that segmenting a network creates more collision domains, even smaller ones, confuses some students. Introduction of STP and VLANs in the CCNA curriculum will require additional discussion for students not familiar with the technical vocabulary.

Students completing this module should be able to perform the following tasks:

- Define bridging and switching
- Describe content-addressable memory (CAM) table
- Define latency
- Describe store-and-forward and cut-through switching modes.
- Explain Spanning-Tree Protocol (STP)
- Define collisions, broadcasts, collision domains, and broadcast domains
- Identify the Layer 1, 2, and 3 devices used to create collision domains and broadcast domains
- Discuss data flow and problems with broadcasts
- Explain network segmentation and list the devices used to create segments

8.1 Ethernet Switching

Essential Labs: none

Optional labs: none

Core TIs: All

Optional TIs: none

Course-level claim: Describe the principles and practice of switching on an Ethernet network.

Hands-on skills: none

8.1.1 Layer 2 bridging

Using Figure 1, explain this series to students and discuss the process by which a bridge learns addresses and how frames are treated. This is the basis for switching and for the spanning tree protocol, both of which are crucial for understanding LAN behavior. Consider kinesthetic activities and role-plays to act out the device algorithms.

8.1.2 Layer 2 switching

Reinforce the concept that switches learn in much the same way as bridges. Switches provide a virtual connection directly between the source and destination nodes, rather than the source and destination collision domain.

To introduce LAN switching discuss the idea of switching in general. Given the number of nodes (n) to interconnect, direct point-to-point connections require $n(n-1)/2$ connections. Therefore, for a fully meshed topology where all nodes (n) can communicate directly with all others, causes the number of connections to become extremely large as n grows. In the old telephone system, one approach to this problem was to create a central node with a human switch operator, making temporary connections. An Ethernet switch is a temporary bridged connection. Another analogy is to draw a crossbar switch. Name the four horizontal lines, input wires, and name the four vertical lines, output wires. Ask students to imagine some intelligent entity that temporarily allows one horizontal and one vertical wire to touch, thereby switching incoming traffic depending upon its destination.

8.1.3 Switch operation

In theory, a switch is simply a multi-port bridge. At this point in the curriculum, questions may arise about Layer 3 or Layer 4 switching. Explain to the students that switching is also done based on IP addressing or TCP port information and that this will be discussed later in the curriculum.

8.1.4 Latency

As described in Modules 3 and 4, there is a propagation delay for the signals traveling along the copper cable, optical fiber, or as microwaves through air. In addition, as signals are processed by network devices, additional delay or latency is introduced. It is important to understand that all networking devices introduce latency. Demonstrate this by having students pass a note from one student to another. A direct transfer is almost immediate, but does take a finite, non-zero, amount of time. If an intermediary is introduced and the note has to be checked for a destination address and then readdressed, the time taken to perform this task is latency. This experiment simulates the process of encapsulation and de-encapsulation. Therefore, the more hands the note passes through, there is greater latency, or delay.

This should be reinforced with OSI Layer diagrams showing the de-encapsulation and re-encapsulation of packets traveling through a variety of devices.

8.1.5 Switch modes

Students should have a good understanding of the two primary switching modes, store and forward and cut-through. The understanding of asynchronous and synchronous is also necessary. At gigabit speeds, store and forward switching is dominant because the latency for waiting for the entire frame is small compared to other latencies.

8.1.6 Spanning-Tree Protocol

Students must know the states and the order of STP. Some advanced students may be familiar with finite state diagrams from digital electronics and software development. A state diagram could be drawn for STP as a way of better understanding the process and remembering the states. A mnemonic device could also help. One used is B-L-L-F-D pronounced “bluffed” in English.

8.2 Collision Domains and Broadcast Domains

Essential Labs: none

Optional labs: none

Core TIs: All

Optional TIs: none

Course-level claim: Describe the principles and practice of switching on an Ethernet network.

Hands-on skills: none

8.2.1 Shared media environments

Reinforce prior learning regarding collision and broadcast domains.

8.2.2 Collision domains

Use the animation in Figure 1 to illustrate the collision domain and resultant collision. Ask the students what device or devices they would implement to make this network more efficient. Experiment with the upcoming packet tracer application.

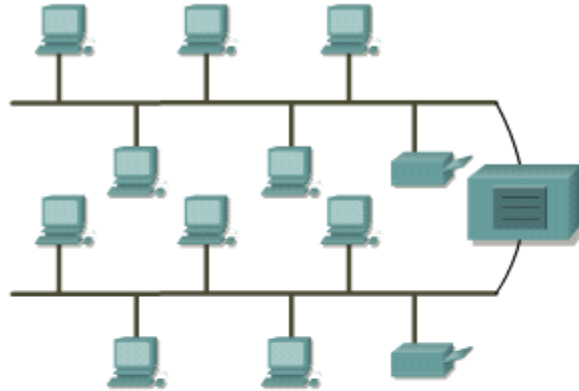
8.2.3 Segmentation

This TI should reinforce the solutions from the question asked in TI 8.2.2. It is important to place the context of this TI in the evolution of devices. Users wanted more distance, so the repeater was developed. They wanted more connectivity, so the multiport repeater or hub was developed. They wanted some traffic control, so a bridge was invented. They wanted traffic control, speed, bandwidth, and connectivity, so the switch was developed. They wanted to connect multiple LANs, so routers solve this issue. Differentiate how bridges, switches, routers, and VLANs, if introduced earlier, are used to segment a network.

Shared Access is a Collision Domain



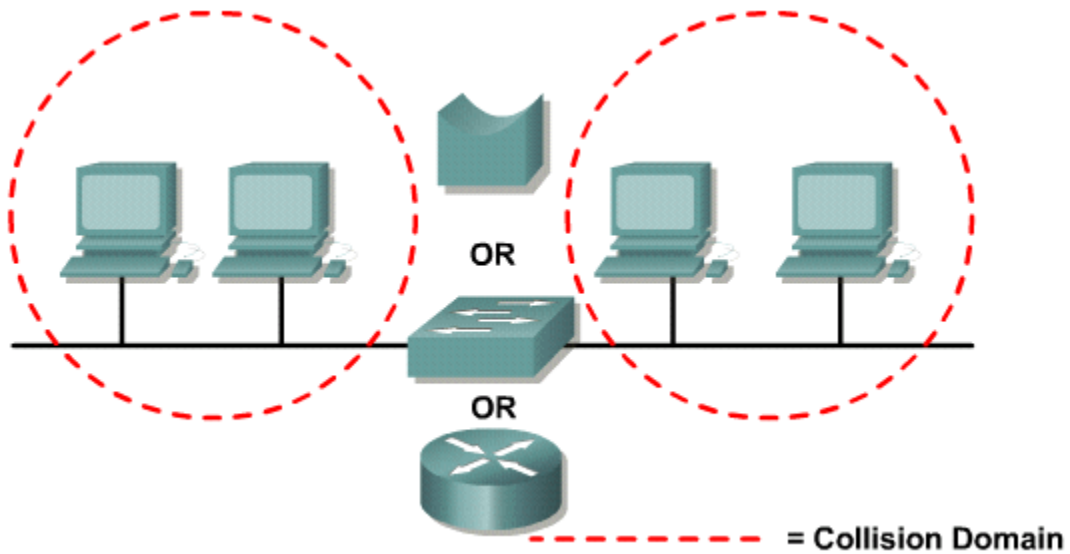
Collision Domain- Extended by Repeater



Collision Domain- Created by hub



Collision Domain- Extended by Repeater



8.2.4 Layer 2 broadcasts

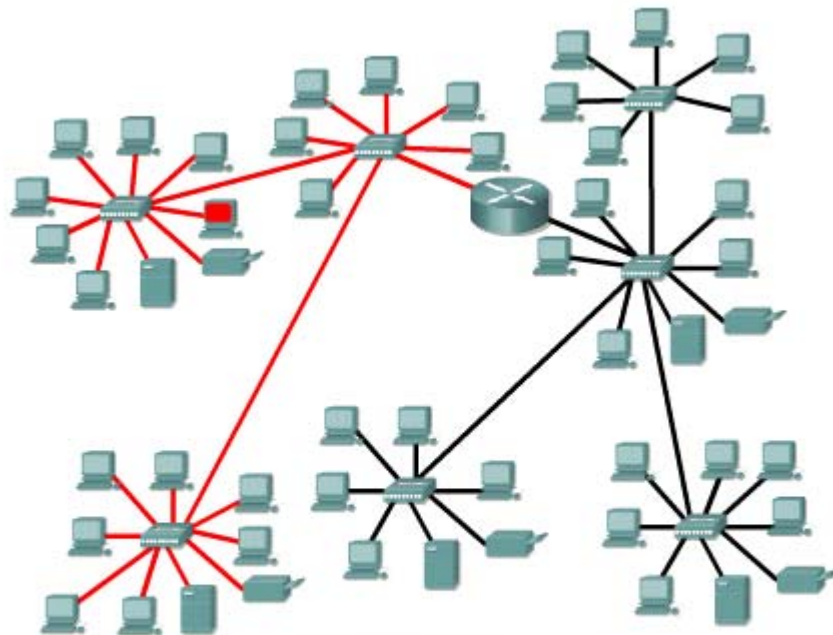
This TI and 8.2.5 should be combined to lessen confusion about Layer 2 and Layer 3 unicasts, multicasts, and broadcasts.

8.2.5 Broadcast domains

It is useful to review some terminology before students encounter this TI. Three generic terms in communications are unicast, multicast, and broadcast. Unicast is one-to-one, multicast is one-to-many, and broadcasts are one-to-all communications.

A possible point of confusion is the use of the word broadcast. This TI is not clear enough on the distinctions between Layer 2 and Layer 3 broadcasts. Layer 2 broadcast refers to the use of the MAC address. However, there are also Layer 3 IP multicasts and broadcasts that involve designated IP addresses. These will be discussed in Modules 9 and 10.

Reinforce the Layer 3 function where routers connect networks and border broadcast domains. The ideas presented here will be very helpful in Modules 9 and 10. Reinforce that routers connect distinct IP networks. Routers must perform the Layer 2 function of switching packets between networks and the Layer 1 function of interfacing with the medium. However, they make this decision based on Layer 3 information.



By using a router in place of a bridging device a layer two broadcast domain is contained. Layer three devices are the only devices that contain broadcasts.

8.2.6 Introduction to data flow

This TI is a good review and application of earlier work on the OSI model. Emphasize that data moving through networking devices can use services up to the network layer, depending on the type of device. A crucial discussion topic is how a frame or packet gets from the source to the destination. Have students create OSI layer data flow diagrams for repeaters, hubs, bridges, switches, routers, and small networks.

8.2.7 What is a network segment?

Segments may consist of two machines or many machines. What devices are used to create these segments is critical to network performance and to a certain extent the security of the network. This TI can be used to answer persistent and understandable misconceptions.

Module 8 Summary

Before moving on to Module 9, the students must be able to explain the basic function of an Ethernet switch and how frames and packets flow in a collision and broadcast domain.

Online assessment options include the Module 8 Quiz in the curriculum and the Module 8 exam. Given a network topology, such as the teaching topology, students should be able to identify collision and broadcast domains. Given the teaching topology with any two workstations specified, the student must be able to diagram the succession of de-encapsulations and encapsulations as packets travel through repeaters, hubs, bridges, switches, and routers.

Students should understand the following main points:

- Bridging and switching evolution
- Content-addressable memory (CAM)
- Bridging latency
- Store-and-forward and cut-through switching modes
- Spanning-Tree Protocol (STP)
- Collisions, broadcasts, collision domains, and broadcast domains
- The Layer 1, 2, and 3 devices used to create collision domains and broadcast domains
- Data flow and problems with broadcasts
- Network segmentation and the devices used to create segments

Module 9: TCP/IP Protocol Suite and IP Addressing

Overview

When teaching Module 9, several questions should be discussed. Discuss why there are two networking models. Also discuss why IP addresses are necessary and why it is important to learn IP addressing. Finally, discuss why processes like ARP are necessary. The answer to these questions may help students put the challenges of Modules 9 and 10 in some context.

Module 9 Caution

The binary mathematics of eight-bit numbers is difficult for students. If the student has not mastered binary math before this module, it will be difficult for them to comprehend the new material. In addition to the binary math, a large amount of new terminology and many special IP address are introduced. Complex processes such as ARP, RARP, BootP, and DHCP are introduced.

Students completing this module should be able to perform the following tasks:

- Explain why the Internet was developed and how TCP/IP fits the design of the Internet
- List the four layers of the TCP/IP model
- Describe the functions of each layer of the TCP/IP model
- Compare the OSI model and the TCP/IP model
- Describe the function and structure of IP addresses
- Understand why subnetting is necessary
- Explain the difference between public and private addressing
- Understand the function of reserved IP addresses
- Explain the use of static and dynamic addressing for a device
- Understand how dynamic addressing can be done using RARP, BootP, and DHCP
- Use ARP to obtain the MAC address to send a packet to another device
- Understand the issues related to addressing between networks

9.1 Introduction to TCP/IP

Essential Labs: none

Optional labs: none

Core TIs: All

Optional TIs: none

Certification-level claim: Evaluate the TCP/IP communication process and its associated protocols.

Course-level claim: Describe how the protocols associated with TCP/IP allow host communication to occur.

Hands-on skills: none

9.1.1 History and future of TCP/IP

The TCP/IP model is equally as important as the OSI model. The OSI model is an ISO standard for worldwide communications that defines a networking framework. The TCP/IP protocols are the core of the Internet. The present version of TCP/IP is based on a 32-bit addressing scheme called IPv4. There is currently a transition being made to IPv6. Students should know that IPv6 is a 128-bit address written in hexadecimal and that the IPv4 to IPv6 transition is complex. Emphasize the importance of IETF RFCs. Students may not be advanced enough to refer to the RFCs at this time. However, students should realize that the IEEE and IETF issue standards that govern Ethernet and TCP/IP respectively, and are the focus of the entire CCNA and CCNP curriculum.

9.1.2 Application layer

Many of the protocols mentioned here are explained in more depth in Module 11. Students should reproduce Figure 1 in 9.1.2 and create a separate page for each layer of the TCP/IP model, as was done for the OSI model. Record the information for each layer shown in RIOS 9.1.2 through 9.1.5.

9.1.3 Transport layer

The two primary transport layer protocols UDP and TCP are discussed in more depth in Module 11.

9.1.4 Internet layer

Modules 9 and 10, and much of CCNA 2 and CCNA 3, deal with this layer.

9.1.5 Network access layer

An example of filling in the details of the TCP/IP network access layer is discussed in Modules 6 and 7. The coverage of WAN technologies in CCNA 4 is another example.

9.1.6 The OSI model and the TCP/IP model

As a class exercise, draw a blank OSI and TCP/IP model on the board. Have each student come up and fill in one or two items on each chart. As the items are filled in, the next person is chosen to come up. This exercise should be repeated throughout the CCNA course. The information acquired from this exercise leads to success on the certification exam.

9.1.7 Internet architecture

The definition of the cloud and the concept of routing tables should be stressed in this TI. This builds upon TIs 5.2.3, 8.2.5, and 8.2.6. This TI needs to be reviewed before moving forward in the curriculum.

9.2 Internet Addresses

Essential Labs: 9.2.7

Optional labs: none

Core TIs: All

Optional TIs: none

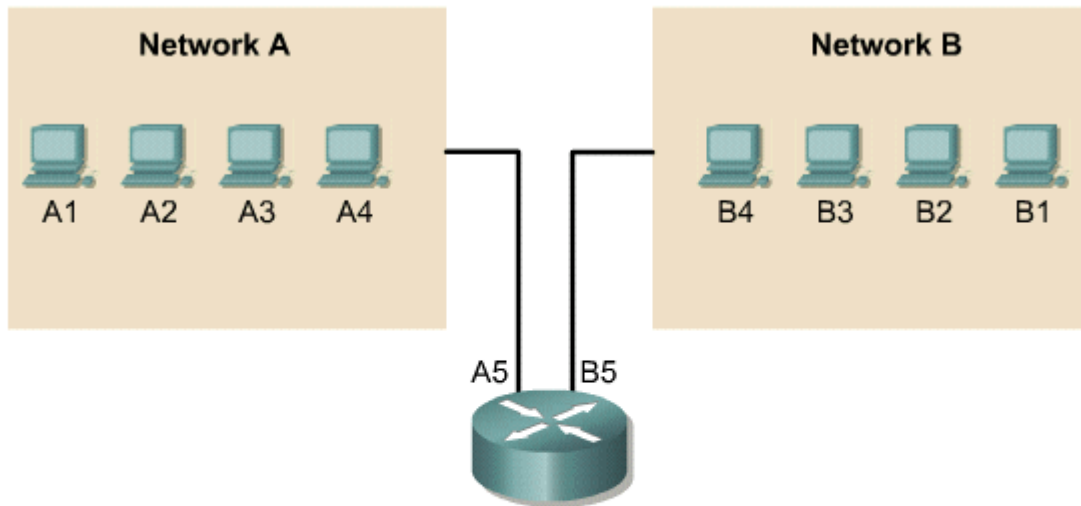
Certification-level claim: Design an IP addressing scheme to meet design requirements.

Course-level claim: Explain and demonstrate the mechanics associated with IP addressing.

Hands-on skills: none

9.2.1 IP addressing

This is an introduction to IP addressing. From the DOS command window, `ping yahoo.com` and make note of the IP address that is displayed. Convert this IP address to binary. Have students `ping` other sites and convert those IP addresses to binary.



While these addresses are not actual network addresses, they represent and show the concept of address grouping. This uses the A or B to identify the network and the number sequence to identify the individual host. The combination of letter (network address) and the number (host address) create a unique address for each device on the network.

9.2.2 Decimal and binary conversion

Figures 4 and 6 are interactive flash calculators. These are provided for additional practice for students to perform binary to decimal and decimal to binary conversions. If other conversions are to be done, use 255 or less. When teaching this TI, use numbers that relate to IP addresses. Understanding binary to decimal conversion is necessary for the student to be successful taking the CCNA exam.

Practice problems

Binary to Decimal Conversion. (using 2 bytes)

Convert the following binary numbers into decimal:

- | | |
|---------------------|--------------------------------------------|
| 1. 1000101101100110 | 35686 = 32768+2048+512+256+64+32+4+2 |
| 2. 0110101101100101 | 27493 = 16384+8192+2048+512+256+64+32+4+1 |
| 3. 0001101101011001 | 7001 = 4096+2048+512+256+64+16+8+1 |
| 4. 1110001110001010 | 58250 = 32768+16384+8192+512+256+128+8+2 |
| 5. 0101111001011010 | 24154 = 16384+4096+2048+1024+512+64+16+8+2 |

Convert the following decimal numbers into binary:

- | | |
|----------|-----------------------------------------------------------|
| 1. 13975 | 0011011010010111 = 8192+4096+1024+512+128+16+4+2+1 |
| 2. 61901 | 1111000111001101 = 32768+16384+8192+4096+256+128+64+8+4+1 |
| 3. 1591 | 0000011000110111 = 1024+512+32+16+4+2+1 |
| 4. 42714 | 1010011011011010 = 32768+8192+1024+512+128+64+16+8+2 |
| 5. 30556 | 0111011101011100 = 16384+8192+4096+1024+512+256+64+16+8+4 |

9.2.3 IPv4 addressing

Students should understand the ranges of IP addresses. The range is the maximum number of hosts and the number of bits that are assigned to the network portion of the address.

Practice problems

Identify the IP Address Class

Look at the following IP addresses and determine if they are class A, B, C, or D.

(Look only at the first number to determine the class.)

- | | |
|-------------------|---------|
| 1. 172.168.46.194 | 172 → B |
| 2. 118.57.251.26 | 118 → A |
| 3. 64.118.32.189 | 64 → A |
| 4. 200.52.157.156 | 200 → C |
| 5. 191.45.133.190 | 191 → B |
| 6. 225.117.117.89 | 225 → D |
| 7. 126.31.111.35 | 126 → A |
| 8. 192.250.16.81 | 192 → C |
| 9. 223.1.199.201 | 223 → C |
| 10. 145.209.40.12 | 145 → B |

9.2.4 Class A, B, C, D, and E IP addresses

Students should now understand the basics of address classes. Now they need to learn that there are two parts to the address, the network and host bits. Figure 1 illustrates the number of octets assigned to each portion in each class. Ensure that students understand that an octet consists of eight bits. Students should also make note of which classes are assigned to which type of entity. Discuss how MAC addresses represent a flat address space and how that is satisfactory for LANs. Discuss that a global WAN needs to be scalable and requires a hierarchical addressing scheme. The use of postal service and telephone analogies can be used where appropriate. Try to avoid declarative statements, such as "the zero subnet is never used". Statements like that will cause problems in CCNA 3 when VLSM and classless addressing is introduced. Have students practice until they have this mastered.

Practice problems

Write the first octet of each IP address in binary, and then determine its class based on the most significant digits.

1. 176.186.14.112 176 = 10110000 → B
2. 197.76.210.100 197 = 11000101 → C
3. 129.118.32.189 129 = 10000001 → B
4. 113.26.172.106 113 = 01110001 → A
5. 201.200.100.90 201 = 11001001 → C
6. 47.145.148.211 47 = 00101111 → A

9.2.5 Reserved IP addresses

Every network has a global, or network, ID and broadcast address. It is important that students understand this before subnetting. This will answer the question as to why there are always two less available addresses than the total number created. The discussion of unicasts and broadcasts refers to Layer 3 IPs.

Practice problems

Write down the network and broadcast addresses for each IP address:

1. IP Address – 210.189.137.100 Subnet Mask – 255.255.255.240

IP Address	210.189.137.100	IP in Binary	11010010.10111101.10001001.01100100
Subnet Mask	255.255.255.240	Mask in Binary	11111111.11111111.11111111.11110000
What Class?	C	Default Mask?	255.255.255.0

	Network part of address (number of octets based on class)	Subnet part of address	Host part of address
IP Address in binary	11010010.10111101.10001001.	0110	0100
Change HOST to Zeros	11010010.10111101.10001001.	0110	0000
Convert address to dotted decimal notation – Subnet Address		210.189.137.96	
Change HOST to Ones	11010010.10111101.10001001.	0110	1111
Convert address to dotted decimal notation – Broadcast Add.		210.189.137.111	

2. IP Address – 180.43.120.39**Subnet Mask – 255.255.255.192**

IP Address	180.43.120.39	IP in Binary	10110100.00101011.01111000.00100111
Subnet Mask	255.255.255.192	Mask in Binary	11111111.11111111.11111111.11000000
What Class?	B	Default Mask?	255.255.0.0

	Network part of address (number of octets based on class)	Subnet part of address	Host part of address
IP Address in binary	10110100.00101011.	01111000.00	100111
Change HOST to Zeros	10110100.00101011.	01111000.00	000000
Convert address to dotted decimal notation – Subnet Address		180.43.120.0	
Change HOST to Ones	10110100.00101011.	01111000.00	111111
Convert address to dotted decimal notation – Broadcast Add.		180.43.120.63	

3. IP Address – 193.8.8.171**Subnet Mask – 255.255.255.224**

IP Address	193.8.8.171	IP in Binary	11000001.00001000.00001000.10101011
Subnet Mask	255.255.255.224	Mask in Binary	11111111.11111111.11111111.11100000
What Class?	C	Default Mask?	255.255.255.0

	Network part of address (number of octets based on class)	Subnet part of address	Host part of address
IP Address in binary	11000001.00001000.00001000.	101	01011
Change HOST to Zeros	11000001.00001000.00001000.	101	00000
Convert address to dotted decimal notation – Subnet Address		193.8.8.160	
Change HOST to Ones	11000001.00001000.00001000.	101	11111
Convert address to dotted decimal notation – Broadcast Add.		193.8.8.191	

9.2.6 Public and private IP addresses

This TI focuses on the use of private addresses for address conservation and the absolute requirement for the use of unique addresses across the boundaries of the Internet. Have students find out the IP address on their machine and classify it.

Practice problems

Identify which of the following addresses are private and which are public:

(Hint: Private addresses: 10.x.x.x, 172.16-31.x.x, 192.168.x.x)

- 178.231.34.43 **Public**
- 10.135.214.213 **Private**
- 172.32.31.115 **Public**
- 192.168.31.200 **Private**
- 200.81.155.77 **Public**

- | | |
|--------------------|---------|
| 6. 172.19.111.110 | Private |
| 7. 10.119.89.116 | Private |
| 8. 198.162.147.16 | Public |
| 9. 174.16.190.32 | Public |
| 10. 172.28.101.222 | Private |

9.2.7 Introduction to subnetting

Using the hierarchical design of the telephone numbering system as an analogy helps students to understand the concept of subnetting. Use the animation in Figure 2 as an analogy. Figure 3 may need to be reviewed for later use unless students are very familiar with subnetting. This TI leads to calculating subnets. It is important to introduce students to the terminology and the role of subnetting.

9.2.8 IPv4 versus IPv6

There is a lot of good background and information in this TI. It includes reasons for subnetting and CIDR as well as the implementation of IPv6. Discuss with students about how IPv6 can be implemented worldwide and what problems could be encountered by doing so.

9.3 Obtaining an IP Address

Essential Labs: 9.3.7

Optional labs: 9.3.5

Core TIs: 9.3.1, 9.3.2, 9.3.5, 9.3.6, and 9.3.7

Optional TIs: 9.3.3 and 9.3.4

Course-level claim: Describe how an IP address is associated with a device interface and the association between physical and logical addressing.

Hands-on skills: Students should be able to do an ARP table lookup.

9.3.1 Obtaining an Internet Address

This TI gives an overview for the process of obtaining an IP address for the network. Have students consider the problem of everyone having the ability to choose their own phone number. Then relate that to the problem of everyone obtaining an IP address to participate in the global Internet.

9.3.2 Static assignment of an IP address

Static address assignment is the administrative task of manually configuring an IP on a workstation. Have the students verify on the classroom systems whether the workstations are using static or dynamic addresses. Create a mini-lab and have the students consider why static IP addressing is not scalable.

9.3.3 RARP IP address assignment

A computer may not know its own IP address. The student needs to become comfortable with the RARP process. Tell the students that a network is a large system of processes and communication. Many aspects of networking that might cause administrative problems become easy to maintain with well-designed protocols.

9.3.4 BOOTP IP address assignment

This TI is just a quick overview of the BOOTP process. BOOTP is not in commonly used today because it has been replaced by DHCP.

9.3.5 DHCP IP address management

The main point of DHCP is not the message details but to start making such a process normal to the student. If the classroom workstations have dynamically assigned, or DHCP, addresses have the students go to the DOS command prompt and issue the command `winipcfg /all` for Windows 9.x, or `ipconfig /all` for Windows 2000 and higher. Have the students make note of the IP address, the time the address lease was obtained, the expiration date of lease, and the length of the lease. Reboot the workstation, and recheck this information and compare it. Is the address the same? Check the address during the next time the class meets. Is the address the same? Has it changed? Ask if the lease expired and if so, why.

9.3.6 Problems in address resolution

Discuss the importance of address resolution. If a source does not know the MAC address of a destination, or the MAC address does not match, a datagram will be discarded by the destination host. Discuss the importance the TCP/IP suite protocol called Address Resolution Protocol (ARP) and how it can automatically obtain MAC addresses for local transmission. Also discuss the different issues that are raised when data is sent outside of the local area network. This is displayed in Figures 1 and 2.

9.3.7 Address Resolution Protocol (ARP)

Discuss the ARP process. Describe to the student how ARP functions, how the addresses are gathered, and what the ARP tables look like on a PC. Use lab 9.3.7 "Workstation ARP" to show the students how to view the workstation ARP table by issuing the `arp -a` command in the DOS command window.

Module 9 Summary

Before moving on to Module 10, the students must be proficient in decimal-to-binary and binary-to-decimal conversion, the nomenclature and format of IP addresses and subnet masks, and the IP address classes.

Online assessment options include the end-of-module online quiz in the curriculum and the online Module 9 exam. Consider giving short numerical quizzes, where IP-related binary calculations are required or where students must come up with numerical examples of different types and ranges of IP addresses.

Students should understand the following main points:

- Why the Internet was developed and how TCP/IP fits the design of the Internet
- The four layers of the TCP/IP model
- The functions of each layer of the TCP/IP model
- The OSI model compared to the TCP/IP model
- IP addressing gives each device on the Internet a unique identifier
- IP address classes are logical divisions of the address space used to meet the needs of various size networks
- Subnetting is used to divide a network into smaller networks
- Reserved addresses fulfill a special role in IP addressing and cannot be used for any other purpose
- Private addresses cannot be routed on the public Internet
- The function of a subnet mask is to map the parts of an IP address that are the network and the host
- Someday IPV4 will be completely obsolete and IPV6 will be the commonly used version
- A computer must have an IP address to communicate on the Internet
- An IP address may be configured statically or dynamically
- A dynamic IP address may be allocated using RARP, BOOTP, or DHCP
- DHCP supplies more information to a client than BOOTP
- DHCP allows computers to be mobile allowing a connection to many different networks
- ARP and Proxy ARP can be used to solve address resolution problems

Module 10: Routing Fundamentals and Subnets

Overview

When teaching Module 10, student motivation may be very important. Encourage the students as they work to master the skill of subnetting. Students may ask why something is done. Respond to the student questions by including the following reasons for understanding subnetting:

- It is vital for any future studies in the CCNA program
- It is done by hand without calculators, and is required to pass the certification exam
- It is a key skill identified by the networking industry as a condition of employment
- It makes a conceptual understanding of routing possible

Module 10 Caution

The concepts of the IP Packet and routing protocols are not simple. The single most difficult task throughout CCNA 1 and CCNA 2 is mastering the skill of subnetting. This module will likely require the most time of any of the eleven modules of CCNA 1. Please plan ahead for this module. The pacing of Modules 1 through 9 must allow for adequate time for practicing subnetting. Lack of mastery of subnetting in this module can interfere with learning more advanced concepts in the rest of the CCNA curriculum.

Students completing this module should be able to perform the following tasks:

- Describe routed protocols
- List the steps of data encapsulation in an internetwork as data is routed to one or more Layer 3 devices
- Describe connectionless and connection-oriented delivery
- Name the IP packet fields
- Describe the process of routing
- Compare and contrast different types of routing protocols
- List and describe several metrics used by routing protocols
- List several uses for subnetting
- Determine the subnet mask for a given situation
- Use a subnet mask to determine the subnet ID

10.1 Routed Protocol

Essential Labs: none

Optional labs: none

Core TIs: All

Optional TIs: none

Certification-level claim: Evaluate TCP/IP communication process and its associated protocols.

Course-level claim: Describe the principles and practice of packet switching utilizing the Internet Protocol (IP).

Hands-on skills: none

10.1.1 Routable and routed protocols

Routable = Routed = a protocol which can be routed

10.1.2 IP as a routed protocol

It is important to remember that IP is a routed protocol versus a routing protocol. Note that IP is two letters and routed ends in 'ed', also two letters. Ethernet was chosen from the competing LAN technologies to become the LAN dial tone. IP was chosen from the competing protocols to be the core of the packet-switched global Internet. They emerged as a consensus over many years of interaction amongst many government agencies, universities, and companies.

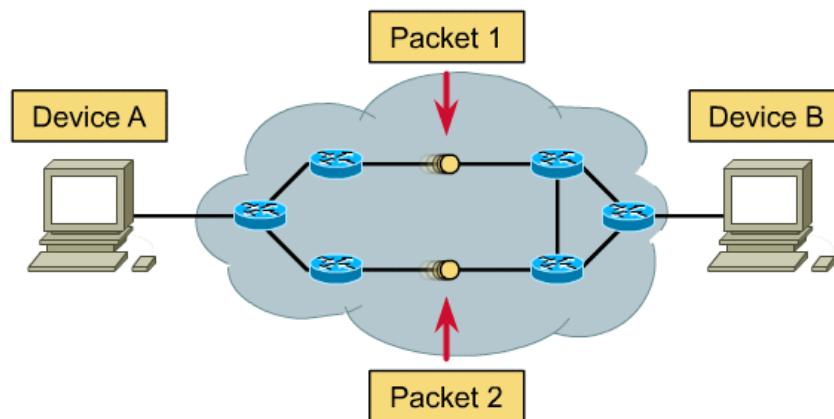
10.1.3 Packet propagation and switching within a router

This TI reinforces the process of encapsulation and de-encapsulation. A Figure 1 activity is to draw a topology with MAC and IP addresses. Have students trace the transformations of Layer 2 and Layer 3 addresses as the packet flows through different devices. An activity for Figure 3 is to have students make flowcharts for the algorithms for repeaters/hubs, and bridges/switches. Then have the students compare them to the routing flowchart. Remind students to be careful about frame/packet distinctions here, which is not as clear in the curriculum as it should be. A kinesthetic activity or role-play could be useful here.

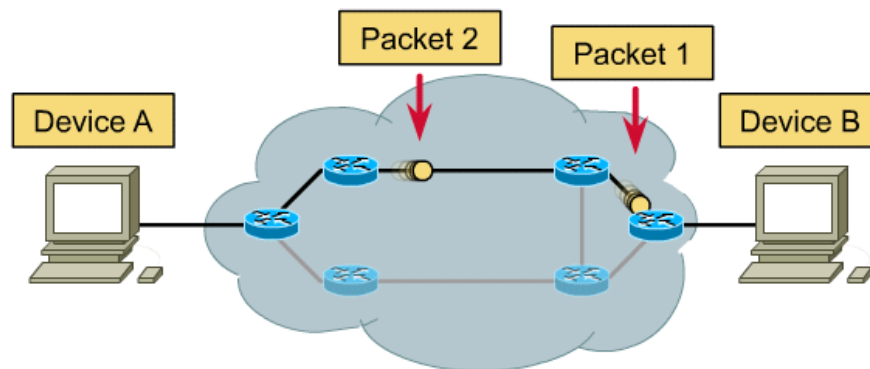
10.1.4 Connectionless and connection-oriented delivery

Make the distinction between connection-oriented and connectionless. Students can usually comprehend phone system versus postal system analogies.

Connectionless Network Services



Connection-Oriented Services



10.1.5 Anatomy of an IP packet

The CCNA curriculum details frame formats, packet formats, message formats, and segment formats throughout the text. However, the Ethernet frame, the IP packet, and the TCP segment are three PDUs that students should study in much more depth.

Not all of the fields of the IP packet are important to the beginner. However, the concept of the source and destination addresses, a data field, and other control information should be clear to the student. The numbers 0 through 31 at the top of the graphic are in bits, not bytes. The diagram is stacked vertically. However, the second row should be appended after the first row, and the third row after the second, and so on. This is after all one long bit stream. Use the web link as a reference. Print out a copy and cut up the paper to see the packet format all on one horizontal line.

10.2 IP Routing Protocols

Essential Labs: none

Optional labs: 10.2.9

Core TIs: All

Optional TIs: none

Certification-level claim: Evaluate the characteristics of routing protocols.

Course-level claim: Describe the concepts associated with routing, and the different methods and protocols used to achieve it.

Hands-on skills: none

10.2.1 Routing overview

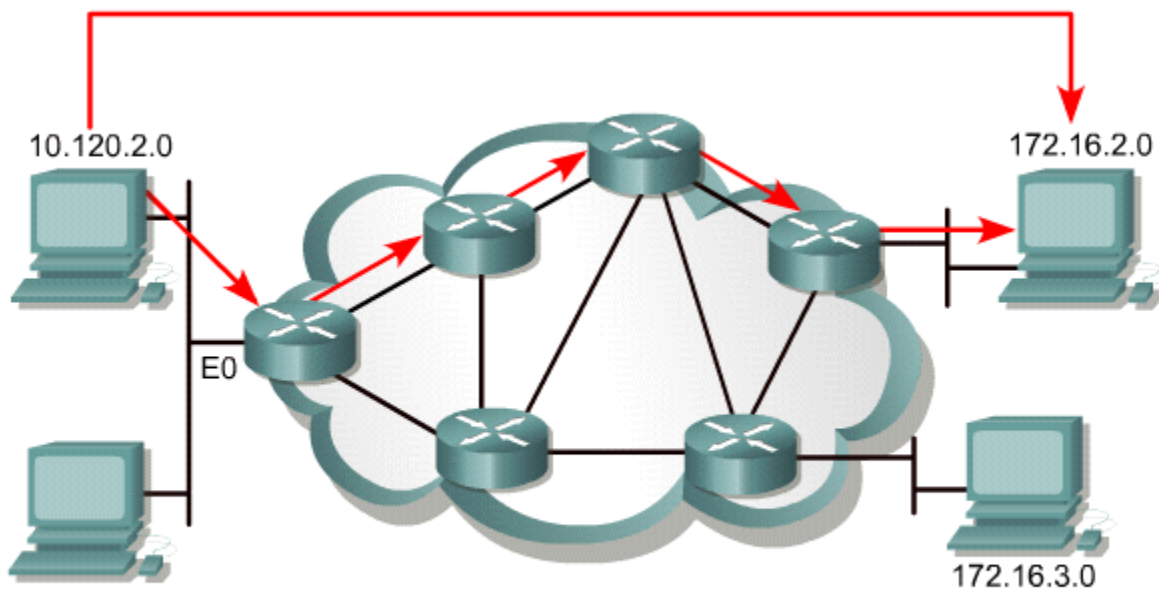
Routing is a Layer 3 function and the principal occupation of routers. Make note of NetBEUI being a non-routable protocol used in peer-to-peer networking. Consider discussing the history of packet-switched networks here as well as the routing problem.

10.2.2 Routing versus switching

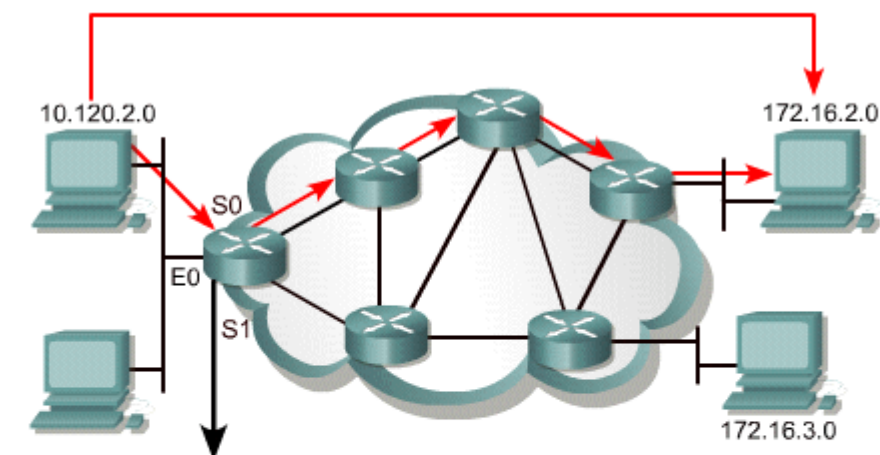
The focus of this TI is to introduce students to Layer 3 routing and Layer 2 switching. Of course, all routers must perform a switching process. There are multilayer switches that make decisions based on Layer 3 information, L3 switching, or a type of conversation such as TCP port number, L4 switching, or other technologies. High-end Cisco switches have routing modules. Have advanced students visit, <http://www.cisco.com/> for additional references. Otherwise, focus on simple distinctions between the routing and switching.

10.2.3 Routed versus routing

Emphasize to students that a routing protocol is inter-router chatter about best paths. Routed protocols carry user data end-to-end through the network. Routing protocols provide communication between routers and the exchange of route information so that routed protocols can be sent to the proper place. This is a concept that is commonly confused throughout the curriculum. Have the students develop a mnemonic to remember the difference between the two types of protocols.



Routed protocol transport data from one end-station to another.



Network Protocol	Destination Network	Exit Interface
Connected	10.120.2.0	E0
RIP	172.16.2.0	S0
IGRP	172.16.3.0	S1

Routing protocols are used between routers to determine paths and maintain routing tables

After the path is determined a router can route a routed protocol

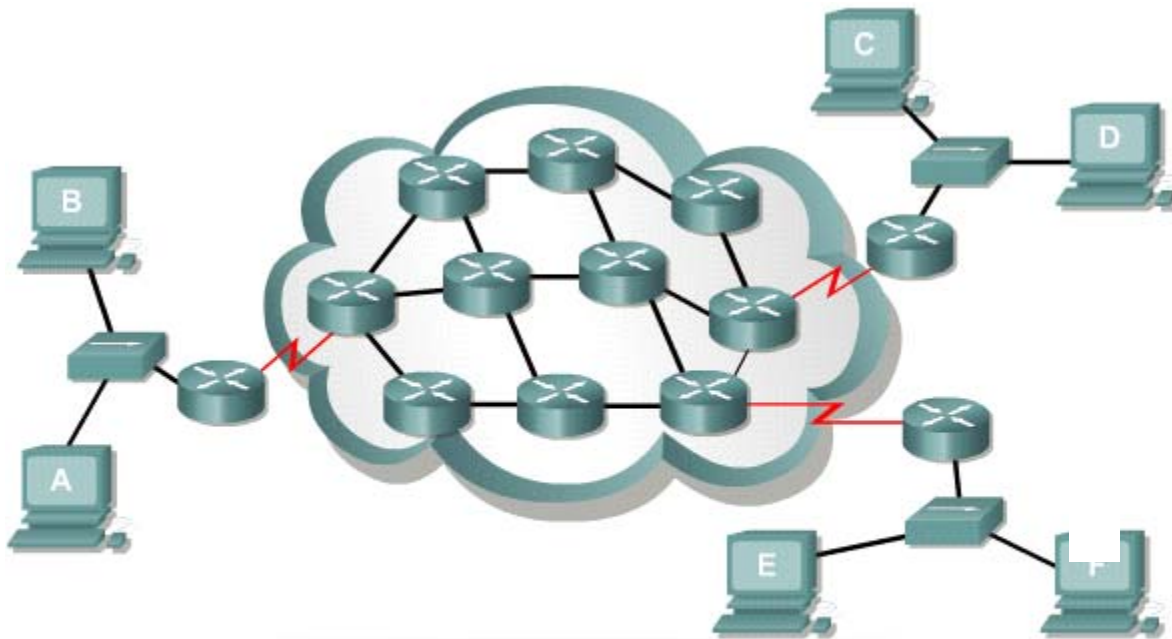
Routing protocol = RIP, IGRP

10.2.4 Path determination

Localize the analogy in Figure 2. Expand upon it using different transportation systems. Analogies have limitations, but they can make this otherwise abstract concept more accessible.

Note that Figure 3 is a network layer function performed by the router. This may seem repetitive but the student must clearly understand this function. This TI is a review of 10.1.3 with a slightly different emphasis.

A crucial distinction missing from the curriculum here is static versus dynamic routing. Discuss with the students the “routing problem”. Here is a global packet-switched network with very dynamic conditions on the node and links and packets need to get through. Have students discuss possible solutions to the problem. If students do not come up with the idea first, suggest the solution that the network administrator predetermines the routes. Discuss the limitations of this approach. See if students come up with dynamic routing, where updates about network conditions are shared among the routers.



If computer A was sending data to computer F, what path would the data take? That is determined by the information in the routing table.



Which is the best route from the house to the university? There are many possible choices, but which is the fastest, the safest, the shortest, and the most reliable? The same questions are asked and answered when routing data.

10.2.5 Routing tables

To reinforce this topic ask the following questions:

- “Why are routing tables necessary?”
- “How do routers build routing tables?”
- “What information is contained in the routing table?”
- “How big a picture of the network topology does the router have?”

This TI helps begin the building of concepts that will be explored in more depth in CCNA 2, where the routing table is a central theme of the course. Briefly discuss how routes get into the routing table through directly connected networks, static routes, and dynamic routing.

10.2.6 Routing algorithms and metrics

Discuss what factors are used to compute the ‘best’ route. Ask if this is a completely dynamic process and if a network administrator can influence this calculation. Lead into a discussion of metrics by comparing no metric at all, as in static routing, to using one metric, such as hops.

10.2.7 IGP and EGP

Differentiate between internal and external routing protocols. Ask the students what the limitations are of each. This TI is primarily to develop important vocabulary for future courses.

10.2.8 Link state and distance vector

Discuss the differences between link-state and distance vector protocols. This should be a simple introduction to a potentially huge topic.

10.2.9 Routing protocols

It is important to remember that RIP is a routing protocol versus a routed protocol. It is also important for the students to remember the family of routing protocols, IGRP, EIGRP, and OSPF. Again, there is the no routing protocol option of static routing. Then there is the simple language of RIP, the more complex language of IGRP, and the complex languages of EIGRP, OSPF, and BGP. The Router Purchase lab is optional, and gives the students a chance to investigate the world of real routers.

10.3 The Mechanics of Subnetting

Essential Labs: none

Optional labs: 10.3.5a, 10.3.5b, 10.3.5c, and 10.3.5d

Core TIs: All

Optional TIs: none

Certification-level claim: Design an IP addressing scheme to meet design requirements.

Course-level claim: Explain and demonstrate the mechanics associated with IP addressing.

Hands-on skills: Assign IP address scheme to an actual LAN or WAN topology.

10.3.1 Classes of network IP addresses

The process of subnetting can be overwhelming for students. It is important to take it slowly and thoroughly cover all facets of the process. By this time, through repetition, students should have a solid grasp on decimal to binary and binary to decimal conversion. Review the IP address classes.

10.3.2 Introduction to and reason for subnetting

There is no substitute for having beginning students write out the four octets worth of bits and start identifying network, subnetwork, and host bits.

10.3.3 Establishing the subnet mask address

Build the subnetting chart gradually on the board as shown in Figures 1 through 3, explaining each step along the way. Again calculate binary numbers using the chart as a manual calculator. Teach the equivalences between decimal, binary, and slash notation formats for expressing subnet masks.

Practice problems

Finding the Subnet Mask

Finding a subnet mask is not all that difficult. One must take two things into consideration when calculating what the subnet mask should be. First is the class of the address and second, is the number of subnets needed. The subnet mask is used with the IP address to identify the network, subnetwork, and host bits, or portion, of an IP address. By default, based on the class of the address, the network portion of the subnet mask is represented by all binary ones, or a decimal 255. The subnet mask for a Class A address without subnetting is 255.0.0.0. The subnet mask for a Class B address, without subnetting, is 255.255.0.0. And the subnet mask for a Class C address, without subnetting, is 255.255.255.0. As subnets are required in a network, the mask is changed by adding to the existing default subnet mask, depending upon the number of subnetworks needed.

Since IP addresses and subnet masks are based upon binary math, the number 2 must be used as the basis for creating subnets. Each time subnets are added to a network, the number of subnets created must be a power of 2.

No. Subnets	Power of 2	Subnet Bits	Mask Number	No. Subnets	Power of 2	Subnet Bits	Mask Number
4 (2 useable)	2^2	11000000	192	8192	2^{13}	11111111.11111000	255.248
8 (6 useable)	2^3	11100000	224	16384	2^{14}	11111111.11111100	255.252
16 (14 useable)	2^4	11110000	240	32768	2^{15}	11111111.11111110	255.254
32 (30 useable)	2^5	11111000	248	65536	2^{16}	11111111.11111111	255.255
64 (60 useable)	2^6	11111100	252	131072	2^{17}	11111111.11111111.10000000	255.255.128
128 (126 useable)	2^7	11111110	254	262144	2^{18}	11111111.11111111.11000000	255.255.192
256 (254 useable)	2^8	11111111	255	524288	2^{19}	11111111.11111111.11100000	255.255.224
512 (510 useable)	2^9	11111111.10000000	255.128	1048576	2^{20}	11111111.11111111.11110000	255.255.240
1024 (- 2=useable)	2^{10}	11111111.11000000	255.192	2097152	2^{21}	11111111.11111111.11111000	255.255.248
2048	2^{11}	11111111.11100000	255.224	4194304	2^{22}	11111111.11111111.11111100	255.255.252
4096	2^{12}	11111111.11110000	255.240				

By default, subnets masks will begin as shown in the following table:

Class A	255.
Class B	255.255.
Class C	255.255.255.

Subnet masks are completed by calculating how many subnetworks are required. From the chart, select the number of useable subnets that is greater than what is required. Next, read across the chart to see how to finish the mask. Since there must be four numbers, or octets, in the subnet mask, put a zero (0) in any remaining places. For example, that is 255.255.224.0.

Practice problems

Look at the following IP addresses and write out the subnet mask based upon the slash notation.

Then, identify the number of useable subnets and hosts per subnet. Follow the steps as indicated in the parentheses.

Advise the students to pay special attention to the class of IP address when determining the number of subnets and hosts.

1. 200.81.155.77/28

/28 in binary is ▼		Subnet Mask in Dotted Decimal format ▼	
(1) 11111111.11111111.11111111.11110000		(2) 255.255.255.240	
Class of this IP Address ►	(3) C	▲ (4) In box (1) cross out the default portion of the subnet mask. Underline the subnet portion of the IP address, which is the remaining 1s.	
(5) Number of Useable Subnets ►	$2^{(\text{number of underlined 1s})} - 2$ $2^4 - 2 = 14$		(6) Number of Hosts per subnet ► $2^{(\text{number of zeros})} - 2$ $2^4 - 2 = 14$

2. 197.66.118.113/27

/27 in binary is ▼		Subnet Mask in Dotted Decimal format ▼	
(1) 11111111.11111111.11111111.11100000		(2) 255.255.255.224	
Class of this IP Address ►	(3) C	▲ (4) In box (1) cross out the default portion of the subnet mask. Underline the subnet portion of the IP address, which is the remaining 1s.	
(5) Number of Useable Subnets ►	$2^{(\text{number of underlined 1s})} - 2$ $2^3 - 2 = 6$		(6) Number of Hosts per subnet ► $2^{(\text{number of zeros})} - 2$ $2^5 - 2 = 30$

3. 151.100.12.211/23

/23 in binary is ▼		Subnet Mask in Dotted Decimal format ▼	
(1) 11111111.11111111.11111110.00000000		(2) 255.255.254. 0	
Class of this IP Address ►	(3) B	▲ (4) In box (1) cross out the default portion of the subnet mask. Underline the subnet portion of the IP address, meaning the remaining 1s.	
(5) Number of Useable Subnets ►	$2^{(\text{number of underlined 1s})} - 2$ $2^7 - 2 = 126$		(6) Number of Hosts per subnet ► $2^{(\text{number of zeros})} - 2$ $2^9 - 2 = 510$

4. 172.17.108.13/25

/25 in binary is ▼		Subnet Mask in Dotted Decimal format ▼	
(1) 11111111.11111111.11111111.10000000		(2) 255.255.255.128	
Class of this IP Address ►	(3) B	▲ (4) In box (1) cross out the default portion of the subnet mask. Underline the subnet portion of the IP address, meaning the remaining 1s.	
(5) Number of Useable Subnets ►	$2^{(\text{number of underlined 1s})} - 2$ $2^9 - 2 = 510$		(6) Number of Hosts per subnet ► $2^{(\text{number of zeros})} - 2$ $2^7 - 2 = 126$

5. 64.28.113.9/26

/26 in binary is ▼		Subnet Mask in Dotted Decimal format ▼	
(1) 11111111.11111111.11111111.11000000		(2) 255.255.255.192	
Class of this IP Address ►	(3) A	▲ (4) In box (1) cross out the default portion of the subnet mask. Underline the subnet portion of the IP address, which is the remaining 1s.	
(5) Number of Useable Subnets ►	$2^{(\text{number of underlined 1s})} - 2$ $2^{18} - 2 = 262,142$		(6) Number of Hosts per subnet ► $2^{(\text{number of zeros})} - 2$ $2^6 - 2 = 62$

10.3.4 Applying the subnet mask

Start the process of subnetting by borrowing three bits, which results in eight subnets. Follow the text in this TI and use a different Class C address to reproduce the format of Figure 1 on the board. Next use four bits and have students fill in the chart. At the next class session, hand the students a blank form and assign an IP address. Have the students fill out the address structure. Continue this process in subsequent classes. Change the number of bits borrowed each time. Students should be able to perform these calculations by hand on paper. There are several subnetting practice problems and worksheets that follow this TI.

Subnetting Worksheet

Network Class? A B ☒ C

Number of subnets needed? Number of bits needed to borrow? n (2^n)

Subnet Mask

Subnet Mask in Binary: ~~11111111.11111111.11111111.11100000~~ Cross Out Default Portion
Underline Subnet Portion

	Subnet (Subnetwork Part)	Host	Subnetwork Address Broadcast Address	Useable Range for Hosts
0	000	00000	0	
	000	11111	31	
1	001	00000	32	33 - 62
	001	11111	63	
2	010	00000	64	65 - 94
	010	11111	95	
3	011	00000	96	97 - 126
	011	11111	127	
4	100	00000	128	129 - 158
	100	11111	159	
5	101	00000	160	161 - 190
	101	11111	191	
6	110	00000	192	193 - 222
	110	11111	223	
7	111	00000	224	
	111	11111	255	
8				
9				
10				
11				
12				
13				
14				
15				

Subnetting Worksheet

Network Class? A B C

Number of Subnets needed? Number of Bits needed to borrow? $n = \text{}^n$)

Subnet Mask

Subnet Mask in Binary:

: Cross Out Default Portion

: Underline Subnet Portion

	Subnet (Subnetwork Part)	Host	Subnetwork Address Broadcast Address	Useable Range for Hosts
0				
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				

10.3.5 Subnetting Class A and B networks

Once Class C subnetting is mastered, Class B and Class A subnetting will be a great deal less complicated. Explain to the students that Classes A and B are just a group of Class Cs. If the first exercise given to them is a Class B with eight bits borrowed, students should immediately see that they have subnetted the Class B into 256 Class Cs. Lab activities are listed as optional because they could be done as homework. Practice is essential because students must master these skills.

To subnet Class A and B addresses, assign problems asking for a certain number of subnets and host addresses.

1. Company XYZ has a 184.113.0.0 network. Create a subnet mask that will divide the network into at least 1000 subnetworks, each with at least 50 hosts.
 - (1) A 1,000 subnets are needed: $2^{10} = 1024$, therefore ten bits must be borrowed.
 - (2) When borrowing ten bits in a class B address, the binary subnet mask, is 11111111.11111111.11111111.11000000. The first 16 bits are "1" by default.
 - (3) Six bits remain as host bits: $2^6 = 64$, there will be 62 useable hosts per subnet.
 - (4) In dotted decimal format, the subnet mask will be 255.255.255.192.
2. The network administrator of HowDee, Inc., is responsible for managing the company's 10.0.0.0 private network address. Create at least 65,000 subnetworks with at least 200 hosts per subnetwork.
 - (1) 65,000 subnets are needed: $2^{16} = 65,536$. Therefore borrow 16 bits.
 - (2) When borrowing 16 bits in a Class A address, the binary subnet mask is 11111111.11111111.11111111.00000000. The first eight bits are "1" by default.
 - (3) Eight bits remain as host bits: $2^8 = 256$, there will be 254 useable hosts per subnet.
 - (4) In dotted decimal format, the subnet mask will be 255.255.255.0.
3. The 172.21.0.0 private network needs to be subnetted. An additional 57 subnets containing about 1000 hosts in each must be provided.
 - (1) 57 subnets are needed: $2^6 = 64$. Therefore borrow six bits.
 - (2) When borrowing six bits in a class B address, the binary subnet mask is 11111111.11111111.11111100.00000000. The first 16 bits are "1" by default.
 - (3) Ten bits remain as host bits: $2^{10} = 1024$, there will be 1022 useable hosts per subnet.
 - (4) In dotted decimal format, the subnet mask will be 255.255.252.0.
4. ClickUm Corp. has a contract for their 10.0.0.0 network to be set up. The requirements are to have around 4000 subnets with about the same number of hosts in each subnetwork.
 - (1) 4,000 subnets: $2^{12} = 4096$. Therefore 12 bits must be borrowed.
 - (2) The binary subnet mask, when borrowing 12 bits in a class A address, is 11111111.11111111.11110000.00000000. The first eight bits are "1" by default.

(3) Twelve bits remain as host bits: $2^{12} = 4096$, there will be 4094 useable hosts per subnet.

(4) In dotted decimal format, the subnet mask will be 255.255.240.0

10.3.6 Calculating the resident subnetwork through ANDing

This concept will be tested on the module final exam and the certification exam. Practice will make this process easier and after gaining an understanding of the process, shorthand techniques may be discovered.

Practice Problems:

Have the students find the subnetwork address. (1) Convert the following IP addresses and subnet masks to binary, (2) then AND the two together underlining the subnetwork part of the ANDed address. Finally, (3) convert the result of the AND back into the dotted decimal format to view what the router looks at to determine the destination subnetwork of a packet.

1. 194.252.190.92 → 11000010.11111100.10111110.01011100
255.255.255.248 → 11111111.11111111.11111111.11111000
11000010.11111100.10111110.01011000 → 194.252.190.88
2. 110.32.63.116 → 01101110.00100000.00111111.01110100
255.255.252.0 → 11111111.11111111.11111100.00000000
01101110.00100000.00111100.00000000 → 110.32.60.0
3. 149.12.126.118 → 10010101.00001100.01111110.01110110
255.255.255.128 → 11111111.11111111.11111111.10000000
10010101.00001100.01111110.00000000 → 149.12.126.0
4. 202.72.40.111 → 11001010.01001000.00101000.01101111
255.255.255.224 → 11111111.11111111.11111111.11100000
11001010.01001000.00101000.01100000 → 202.72.40.96
5. 163.80.113.211 → 10100011.01010000.01110001.11010011
255.255.254.0 → 11111111.11111111.11111110.00000000
10100011.01010000.01110000.00000000 → 163.80.112.0

CCNA 1

Subnetting Test

NAME: _____

1. What class is this address in? 191.24.56.21 **Class B**
2. The host address in #1 is in some network. What is the network address of that network? **191.24.0.0**
3. What is the broadcast address for the network in #2? **191.24.255.255**
4. Which class has host/network octets like this: N.N.N.H **Class C**
5. Which class has host/network octets like this: N.H.H.H **Class A**
6. Approximately how many different Class B networks are there? **65,000**
7. Exactly how many host addresses are on each Class C network? **256**
8. Approximately how many host addresses are on each Class A network? **16 million**
9. Convert to decimal: 11110000 **240**
10. Convert to binary: 252 **11111100**
11. What is the maximum number of host bits that can be borrowed for subnetting from a Class B address? **14**
12. Name two reasons for subnetting.
 - **Controls broadcasts**
 - **Do not need to purchase more network addresses if more networks are needed**

Module 10 Summary

Before moving on to Module 11, the students must be proficient in subnetting. The student must have an ability to describe the IP packet in some detail and to distinguish, both in name and in justification, between routed and routing protocols.

Online assessment options include the end-of-module online quiz in the curriculum and the online Module 10 exam. As a performance assessment, give students a simple topology to cable and build. Give the students an IP address and a scenario with which to start. Have students complete the IP addressing design and apply it to the actual network they have built. Students should be able to configure the IP addresses on the workstation. They will not yet know how to use IOS to configure IP addresses on switches and routers.

Students should understand the following main points:

- Routed or routable protocol characteristics
- The steps of data encapsulation in an internetwork as data is routed to one or more Layer 3 devices
- Connectionless and connection-oriented delivery
- The IP packet fields
- Routers operate at the network layer. Initially, the router receives a Layer 2 frame with a Layer 3 packet encapsulated within it. The router must strip off the Layer 2 frame and examine the Layer 3 packet. When the router is ready to transmit the packet, the router then must encapsulate the Layer 3 packet in a new Layer 2 frame.
- Routed protocols define the format and use of the fields within a packet. Packets generally are conveyed from end system to end system.
- LAN switching occurs at Layer 2 of the OSI reference model, and routing occurs at Layer 3.
- Routing protocols are used between routers to determine paths and maintain routing tables. Routed protocols are used to transport user traffic.
- Routing involves two basic activities: determining the best routing paths and transporting packets through an internetwork.
- Routing algorithms process routing updates and populate the routing table with the best routes.
- Routing tables contain the best routes to all known networks. These routes can be either static routes, which are entered manually, or dynamic routes, which are learned through routing protocols.
- Convergence describes the speed at which all routers agree on a change in the network.
- Interior routing protocols route data within autonomous systems, while exterior routing protocols route data between autonomous systems.
- Routers using distance-vector routing protocols periodically send routing updates consisting of all or part of its routing table. Routers using link-state routing protocols use link-state advertisements (LSAs) to send updates only when topological changes occur in the network, and send complete routing tables much less frequently.
- The uses for subnetting

- How to determine the appropriate subnet mask for a given situation
- How to subnet Class A, B, and C networks
- How to use a subnet mask to determine the subnet ID

Module 11: TCP/IP Transport and Application Layer

Overview

There may not be much time to teach Module 11 in this course. This module is relatively short, has only one lab and no mathematics. The material on TCP is of central importance, but is reviewed in CCNA 2. Focus on how the TCP segment contains provisions for reliability, while the IP Packet and Ethernet frame do not. The lesson on application layer protocols is descriptive information. Many of the protocols may be familiar since they have been mentioned and used throughout the course.

Module 11 Caution

TCP processes such as handshakes and flow control can be difficult when first encountered.

Students completing this module should be able to perform the following tasks:

- Describe the functions of the TCP/IP transport layer
- Describe flow control
- Describe the processes of establishing a connection between peer systems
- Describe windowing
- Describe acknowledgment
- Identify and describe transport layer protocols
- Describe TCP and UDP header formats
- Describe TCP and UDP port numbers
- List the major protocols of the TCP/IP application layer
- Provide a brief description of the features and operation of well-known TCP/IP applications

11.1 TCP/IP Transport Layer

Essential Labs: none

Optional labs: none

Core TIs: All

Optional TIs: none

Certification-level claim: Evaluate TCP/IP communication process and its associated protocols.

Course-level claim: Describe the fundamental concepts associated with transport layer protocols and compare the connectionless approach to transport with the connection oriented one.

Hands-on skills: none

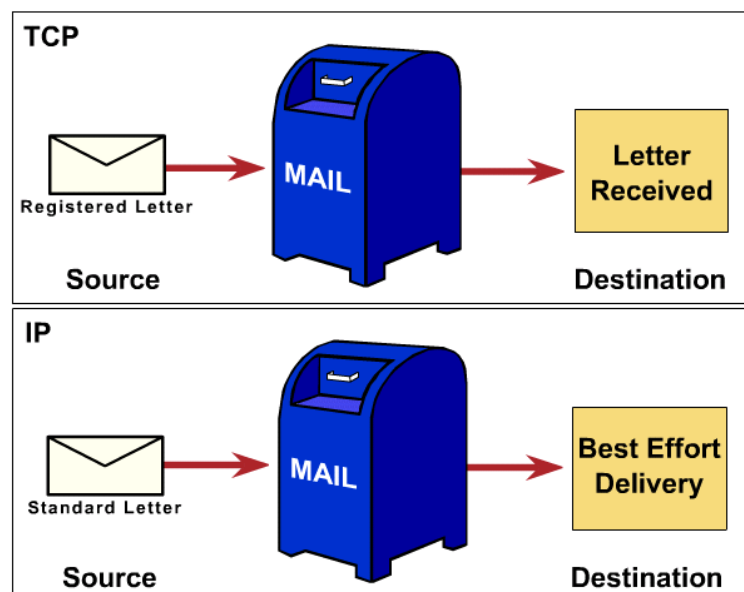
Note

Consider an alternative presentation of this lesson. Have a general discussion of what might happen at Layer 4. Start with multiplexing of conversations and port numbers. Introduce UDP packet segment. Critique UDP. In addition to the need for multiplexing, suggest additional problems of reliability and flow control. Give an overview of the ideas of session, handshakes, and acknowledgments. Introduce the TCP segment. Finish with flow control. An alternative TI sequence could be: 11.1.1, 11.1.9, 11.1.8, 11.1.3, 11.1.4, 11.1.6, 11.1.7, and 11.1.5.

11.1.1 Introduction to the TCP/IP transport layer

Have students refer back to the initial TCP/IP chart that the students created earlier in the course. Add the new information contained in this TI.

TCP and IP



11.1.2 Flow control

Try a role-play where flow control is an issue. Students can use different languages or dialects or just speak very fast, to demonstrate this. Analyze what issues come up and how people address them in spoken communications.

11.1.3 Session establishment, maintenance, and termination

Figure 1 and paragraph 1 do not focus enough on the idea of multiplexing. The simple approach to Layer 4 is to allow different conversations to occur simultaneously over one communications channel. This many to one process is called multiplexing. The inverse one to many processes on the receiving end is called demultiplexing. Multiplexing can be implemented by labeling different types of conversations with port numbers and to “segment” data with these numbers. A protocol UDP, which will be described later, does just that. Note that word “port” used here refers to software distinctions not a physical interface, jack, or port. Graphics 2 and 3 are talking abstractly about what TCP, not UDP, does.

11.1.4 Three-way handshake

There are a couple of things to remember about the three-way handshake. Students should know how TCP tracks bytes and that the vertical axis is a timeline. Therefore, no arrows should be horizontal, because any communication from Point A to Point B takes at least some time. Consider a kinesthetic activity or role-play, first with one byte at a time.

11.1.5 Windowing

It may help if the students act this TI out. Start with “window” size of one word at a time. Then increase the number of windows and the students will see how rapidly their short-term memory buffers become overwhelmed. Now decide on an acceptable speed. Figure 2 lines should be horizontal, but slight tilted. This happens because the vertical dimension is time and all communications take some finite amount of time to occur.

Workstation		Server
Workstation begins three-way handshake →		
Seq 8405231	→→→→→→→→→→→→→→→→→→	
	← Server sends its initial sequence no. and ACK	
	←←←←←←←←←←←←←←←←←←	Seq 190142 ACK 8405232
Workstation ACKs and sends window size →		
ACK 190143 Window 6kb	→→→→→→→→→→→→→→→→→→	
	← Server sends 6kb divided into 1500 byte packets (MTU)	
	←←←←←←←←←←←←←←←←←←	Seq 190143 1500 bytes sent
	←←←←←←←←←←←←←←←←←←	Seq 191643 1500 bytes sent
	←←←←←←←←←←←←←←←←←←	Seq 193143 1500 bytes sent
	←←←←←←←←←←←←←←←←←←	Seq 194643 1500 bytes sent
Workstation ACKs all 6kb of data received, new window size →		
ACK 196143 Window 9kb	→→→→→→→→→→→→→→→→→→	
	← Server sends 9kb divided into 1500 byte packets (MTU)	
	←←←←←←←←←←←←←←←←←←	Seq 196143 1500 bytes sent
	←←←←←←←←←←←←←←←←←←	Seq 197643 1500 bytes sent
	←←←←←←←←←←←←←←←←←←	Seq 199143 1500 bytes sent
	←←←←←←←←←←←←←←←←←←	Seq 200643 1500 bytes sent
	←←←←←←←←←←←←←←←←←←	Seq 202143 1500 bytes sent
	←←←←←←←←←←←←←←←←←←	Seq 203643 1500 bytes sent
Workstation ACKs all 9kb of data received, new window size →		
ACK 205143 Window 3kb	→→→→→→→→→→→→→→→→→→	
	← Server sends 3kb divided into 1500 byte packets (MTU)	
	←←←←←←←←←←←←←←←←←←	Seq 205143 1500 bytes sent
	←←←←←←←←←←←←←←←←←←	Seq 206643 1500 bytes sent
Workstation ACKs all 3kb of data received, new window size →		
ACK 208143 Window 12kb	→→→→→→→→→→→→→→→→→→	
	←←←←←←←←←←←←←←←←←←	... Until entire file is sent

11.1.6 Acknowledgment

Numbering SYN and ACK bytes can be difficult. Therefore, work through a couple of numerical examples.

11.1.7 TCP

Many times in the curriculum, details about frame formats, packet formats, message formats, and segment formats are included for completeness. However there are three PDUs which students should study in much more depth: Ethernet frames, IP Packets, and TCP segments. Not all of the fields are important to the beginner, but the concept of source and destination addresses, a data field, and other control information should be clear to the student. The numbers 0 –31 at the top of graphic are in bits, not bytes. The diagram is stacked vertically. However, the second row really should be appended after the first row, and the third row after the second, and so on. This is after all one long bits stream. Perhaps printing out a copy and cutting up the paper to see the packet format all on one horizontal line will help the students. The main features of TCP are multiplexing, reliability, and flow control. Ask students which application layer protocols use TCP. Emphasize that TCP provides the reliability that neither Ethernet nor IP can provide. Use a postal delivery analogy like delivery with confirmation.

11.1.8 UDP

The main feature of UDP is multiplexing. Discuss what application protocols use UDP. Use a postal delivery analogy, such as delivery without confirmation.

11.1.9 TCP and UDP port numbers

The port numbers in Figure 1 should be noted in the engineering journal, as they will be seen again. Consider having students commit ports 21, 23, 25, 53, 69, and 80 to memory. Distinguish between software and hardware ports. Students who are familiar with ports and security issues could discuss them with the class.

11.2 The Application Layer

Essential Labs: 11.2.4

Optional labs: none

Core TIs: All

Optional TIs: none

Certification-level claim: Evaluate TCP/IP communication process and its associated protocols.

Course-level claim: List the major TCP/IP application protocols, and briefly define their features and operation.

Hands-On Skill: Use protocol analysis software to capture an HTTP transaction.

11.2.1 Introduction to the TCP/IP application layer

Build upon the prior knowledge students have of the TCP/IP and OSI models.

11.2.2 DNS

Most users of the Internet have some familiarity with DNS. Build the lesson on this concept.

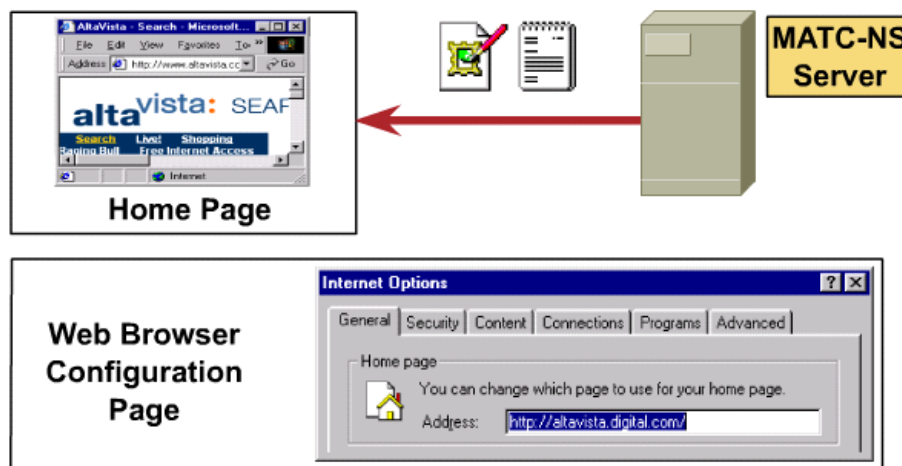
11.2.3 FTP and TFTP

In either CCNA 1 or CCNA 2, it would be very useful for students to understand how to actually use FTP to transfer a file. Consider doing a short lab on this TI.

11.2.4 HTTP

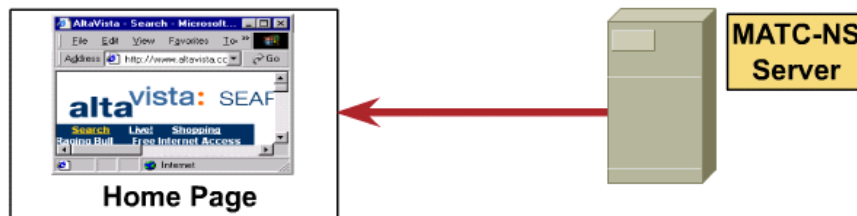
The “Protocol Inspector, TCP, and HTTP” lab is required. Use any protocol analysis software that is available to the school. Examine HTTP at work to provide a powerful review of OSI layers and PDUs, and details about how TCP works. This is a lesson that enables the students to understand exactly what happens when a user clicks **Enter** in a browser.

Make a Connection - Break a Connection



When a browser opens, it is connected to its default home page and the files which make up that page are transferred to the client. This is controlled by the address that is entered into the control page screen of the browser. In the case of Internet Explorer, the page is found under the **TOOLS** menu choice, followed by the **INTERNET OPTIONS** choice.

Make a Connection - Break a Connection



When a browser receives the homepage files, they are contained in the client's memory. The connection with the web server is not needed and is disconnected.

Make a Connection - Break a Connection



When a new URL is entered into the browser's address line, the browser establishes a connection with the new web server.

Make a Connection - Break a Connection



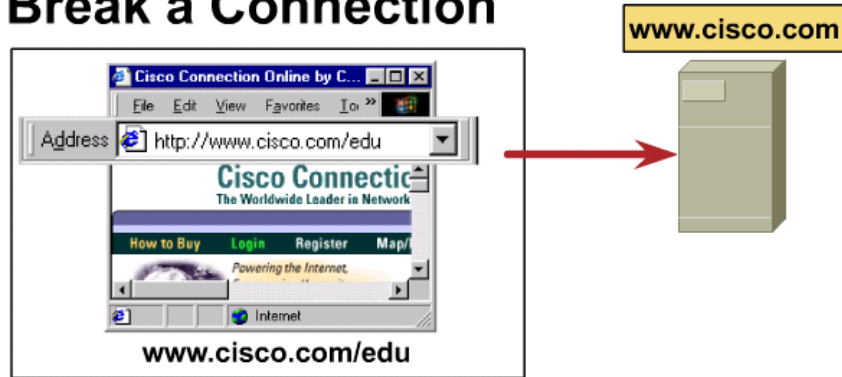
With the connection established, the web server transfers all the files needed to create this web page on the client's browser.

Make a Connection - Break a Connection



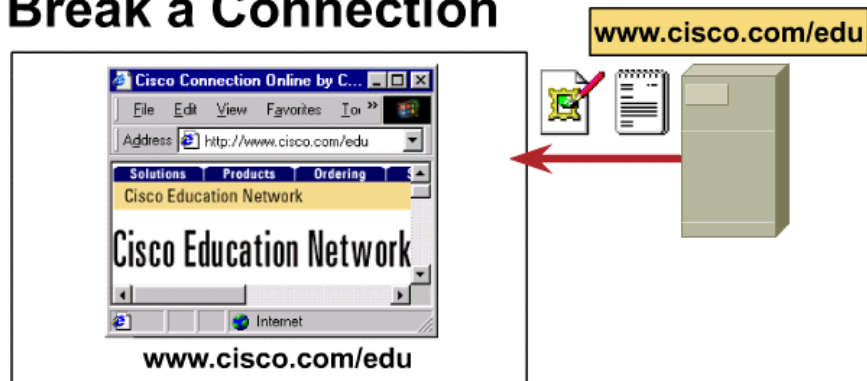
In the same way that the homepage files were stored, the www.cisco.com files are now stored in the browser's memory and cache files. The connection to the web server is no longer necessary, and is disconnected.

Make a Connection - Break a Connection



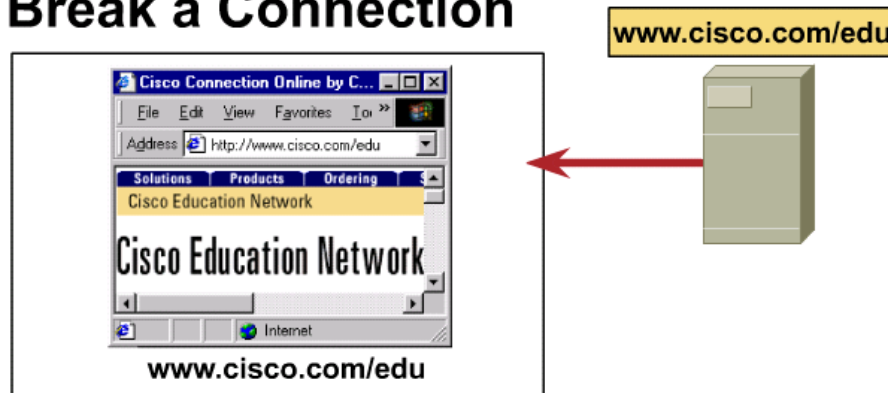
Even when the page that is requested next is on the same website as the current page, the client still must re-establish a connection to the web server.

Make a Connection - Break a Connection



The files needed to create this web page on the client's browser are transferred.

Make a Connection - Break a Connection



Once the files have finished transferring, the web server is again disconnected.

11.2.5 SMTP

Discuss the email system of the school with the students.

11.2.6 SNMP

The relevance of SNMP here is that it provides a means of remotely learning about other devices. Emphasize the importance of this remote monitoring in a geographically distributed network.

11.2.7 Telnet

Consider having students use the local Telnet client to telnet somewhere. This will become very important when taking CCNA 2 through 4.

Module 11 Summary

To be ready for final exam questions the student should be familiar with the terminology of each of the TCP/IP transport and application layer protocols discussed.

Online assessment options include the end-of-module online quiz in the curriculum and the online Module 11 exam. Consider giving students a blank Ethernet frame, a partially blank IP packet, and a partially blank TCP segment. Have students label the names, number of bits or bytes, and functions of these three PDUs. All of these have fundamental importance for the rest of their education as networking professionals.

Students should understand the following main points:

- The functions of the TCP/IP transport layer
- Flow control
- The processes of establishing a connection between peer systems
- Windowing
- Acknowledgment
- Transport layer protocols
- TCP and UDP header formats
- TCP and UDP port numbers
- The processes and protocols at the TCP/IP application layer
- Domain Name Services
- File Transfer Protocols
- Simple Mail Transfer Protocol
- Simple Network Management Protocol
- Telnet

IV. Case Study: Structured Cabling

Module Caution

This module could require a large amount of preparation. Because of implementation challenge and timing during a semester, there will be temptations to skip this case study. However, try to come up with even a small case study that would be of interest to the students.

Structured Cabling Case Study and Installation Project

Structured cabling skills are crucial for any networking professional. Structured cabling creates a physical topology where telecommunications cabling is organized into hierarchical termination and interconnection structures according to standards. The word telecommunications is used to express the necessity of dealing with electrical power wires, telephone wires, and cable television coaxial cable in addition to copper and optical networking media.

Structured cabling is implemented at Layer 1 of the OSI model. Without Layer 1 connectivity, Layer 2 switching, and Layer 3 routing, data transfer across a physical medium from one device to the next is not possible. People new to the networking workforce will find that many of the day-to-day jobs deal with structured cabling.

Many different standards are used to define the rules of structured cabling. These standards vary around the world. Three standards of central importance in structured cabling are ANSI TIA/EIA-T568-B, ISO/IEC 11801, and IEEE 802.x.

The instructor will provide the materials for a structured cabling case study and installation project appropriate to their particular region of the world. It is recommended to complete a structured cabling case study on paper and a hands-on structured cabling installation project. Understanding structured cabling is essential for network administrators, network technicians, and network engineers.

The following links provide additional structured cabling resources:

- <http://www.ieee.org>
- <http://www.tiaonline.org>
- <http://www.iso.org>
- <http://www.linktionary.com/linktionary.html>
- <http://siemon.com>
- <http://www.netday.org>

CCNA 1 Case Study Instructor Guidelines and Solution

Introduction / Objectives

This case study focuses on the key LAN design knowledge areas and skills developed in CCNA 1. These include structured cabling concepts (Layer 1) as well as MAC (Layer 2) and IP addressing (Layer 3). This instructor guide provides an overview of the case study requirements, references to available requirements documentation as well as guidelines for developing the case study and assessing the results.

The main goal of the case study is to have students start with a basic set of requirements, including building and construction documents, then develop a standards-based LAN design to satisfy the requirements. The design and associated deliverable documents will encompass Layer 1 connectivity; Layer 2 switching, and Layer 3 routing. A sample set of documents is provided at the end of this guide as a potential solution to the case study.

Structured cabling skills are crucial for any networking professional. Especially for people new to the networking workforce, many of the day-to-day jobs deal with structured cabling. Telecommunications can deal with many different types of cable including: electrical power wires, telephone wires, and cable television coaxial cable in addition to copper and optical networking media. This case study focuses on the use of copper and fiber-optic data cabling using structured cabling standards.

Preparation for Case Study

Questions before beginning:

1. Do the students have adequate Internet access, within class time, before school and after school, during lunch, or at home, to assure that they can access the CCNA 1 curriculum, Academy Connection, research, and other Internet web sites?
2. Do the students have access to the software they will need to do the case study? Examples include a word processing program such as Word, a spreadsheet program such as Excel, and simple graphics programs such as Paint or Visio.
3. Are these programs familiar to the students or are people who are familiar with this software available to guide the students effectively through documenting their case study?
4. Does the student have a basic understanding of architectural drawings? The following set of activities can be done at once or spread out over several weeks to help visualize various networking issues when working with architectural drawings.

Networking Technicians should be able to do the following:

Draw the floor plan of an existing room to scale. For example, 1/4 inch = 1 foot.

Visualize a room or a set of rooms expressed in an architectural floor plan in “plan view”, looking down on the floor plan, “elevation view”, looking at the room or building from the side or end, and “section view”, looking at a cross section of a room, building, or an area.

Estimate the length of a cable run using only a floor plan.

Rationale

Networking students usually have little drawing experience and no experience with standard architectural drawing projections. This is a disadvantage to a practicing technician, as they must be able to accurately interpret floor plans and cross sections of the building that contains the network.

This is so that they can make informed decisions about network topologies, the amount of materials needed for a particular job, and the equipment required for installation. Furthermore, they must be able to accurately annotate such drawings for future reference.

Localization/Standards

The instructor will provide the materials for a LAN design and a structured cabling installation project (optional) appropriate to their region of the world. It is recommended to complete the LAN design on paper, and, if possible, a hands-on structured cabling installation project.

Many different standards are used to define the rules of structured cabling. These standards vary around the world. Three standards of central importance in structured cabling are ANSI TIA/EIA-T568-B, ISO/IEC 11801, and IEEE 802.x.

The following links provide additional structured cabling resources:

- <http://www.ieee.org>
- <http://www.tiaonline.org>
- <http://www.iso.org>
- <http://www.linktionary.com/linktionary.html>
- <http://www.siemon.com>
- <http://www.netday.org>

Case Study Requirements Documents and Background Information

Case Study Materials Packet

This is a set of network and building design documents (pdfs), which will serve as the basic requirements for the case study. Note that not all of these documents may be required to design the LAN. These documents should be downloaded and provided to the students by the instructor and include the following:

1. Instructions from the President of Farb Software to the IT support staff regarding the development of a network infrastructure plan for the new building.
2. General requirements for servers, software and IP addressing.
3. Floor plans with desk assignments for the two floors of the building. These can be copied and used to show MDF/IDF locations and cable runs.
4. Floor plans with plumbing and HVAC for the two floors of the building.
5. Floor plans with room locations for the two floors of the building.
6. Floor plans with electric, telephone, and lighting for the two floors of the building.
7. Cross-section view showing ceiling construction.
8. Side view showing ceiling construction.
9. Legend showing icons used in building plans.

Panduit Structured Cabling Supplement

This pdf document contains structured cabling background information and graphics that can be used in preparation for the case study. The full Panduit Structured Cabling Supplement, which includes labs, can be accessed and downloaded from the Case Study. This is the last module in the CCNA 1 online curriculum.

Administration of Case Study

It is recommended that students work in teams of three to five. Early in the course, download the case study materials packet and make either hardcopies or electronic copies for each team. Module 3 introduces networking media. These can be used throughout the course to reinforce Layer 1 and LAN design concepts. Attention should be drawn to the Panduit Structured Cabling supplement early in the course. The assignment of the structured cabling portion of the case study should be done along with Module 3 Networking Media. This portion should be completed prior to assigning the IP addressing portion of the case study in conjunction with Module 9 TCP/IP protocol Suite and IP Addressing. All case studies should be completed prior to the end of the school term to allow sufficient time for grading, review of designs, and discussion with the class.

Assessment / Deliverables

What defines a completed CCNA 1 Case Study? The instructor has the ultimate decision as to what written, or electronic, work is needed from the students. The following are some suggestions as to what instructors might want from this case study.

A rubric for documentation to be created and distributed to the students when the case study is introduced is strongly recommended. This way every student group knows exactly what is expected of them. The importance of documentation can not be overemphasized to the students. It is an integral part of their professional training. Virtually every institution and every network has a horror story to tell as the result of improper or nonexistent documentation.

Deliverables

The choice as to which deliverables will be required is up to the instructor. Deliverables for the Farb LAN design, as outlined here, are based on the memo from Cheryl Farb to the Internal Support Team. These may include any or all of the following, but a recommended minimum includes the first six documents listed under "Recommended Documentation". Samples of the recommended deliverables documentation with solutions are provided with this guide as a starting point. These may be modified as necessary. These documents represent one possible solution to the case study and there are many others. The following information on what should be in the recommended documentation should be provided to the students so they know what is expected. The grading rubric can also be based on these requirements.

Recommended Documentation

1. Recommendations for network electronic equipment (table)

This table should show the switches and routers with model numbers and locations, MDF or IDF. Students should research manufacturers web sites for networking equipment in order to specify the proper characteristics and features to support the network design. The network equipment can vary considerably depending on whether VLANs, which will be introduced in CCNA 3, are employed. If VLANs are used, a central switch with a router, either internal or external, can be placed in the MDF and used to route between departmental subnets. If VLANs are not used, the workstations in each subnet must be attached to the same physical switch, or group of switches, which then must attach to a router. This can mean an increased number of routers, one per subnet. These would likely be placed in the IDFs and uplinked back to a central switch. Alternately, a centralized router with multiple Ethernet ports, one per subnet, could be placed in the MDF and the remote switches uplinked to it. For the equipment specification purposes of this case study, assume there are four subnets and specify the equipment necessary to connect them physically and route between them. Another option is to assume the use of VLANs and specify a centralized router or Layer 3 aggregation switch as shown in the table.

2. Recommendations on cabling and passive network components (table)

This document should specify cabling types to be used, where they will be used, and why. An estimate of the total required length for each cable type, in meters and feet, should be provided. It should also specify the type and number of patch cables and wall jacks. The type, size, and location of distribution racks and patch panels, number of ports, should be indicated.

Quantities of cable will vary depending on the number of runs to each work area. It may be desirable to provide two data outlets per work area and at least one to rooms that do not have a workstation in them, to allow for growth. Total horizontal cabling required can be estimated by multiplying the number of runs by an average run length, for example 100 ft or 30m, and then adding a percentage.

3. Horizontal and vertical logical network layout (diagram)

This is a Layer 1 hierarchical diagram showing the MDF and IDFs and their relationships. Major cable types between these locations should be identified as shown here.

4. Horizontal and vertical physical cable layout (diagram)

These are created by marking up the floor plans, showing MDF and IDF locations, and cable runs and bundles. Although the MDF will likely be located with the POP on the first floor, there are several potential locations for IDFs. Color-coding should be used to identify MDFs and IDFs. Different colors should be used to indicate Horizontal cross-connects (HCC), UTP copper cabling, vertical cross-connects (VCC), and fiber cabling.

Note that cable runs will generally follow the cable trays in the ceiling, and are usually aligned with hallways. The exact location of each cable will be determined by the cable installers and is influenced by the location of the network device it serves and the building structures along its path.

Fiber optic cable is recommended for vertical or backbone cabling in this LAN design, although Cat5e copper could suffice based strictly on the distance between MDF and IDFs. Fiber is chosen due to its superior bandwidth, or data carrying capacity, electrical ground isolation capabilities, and resistance to electrical and radio interference.

5. Cable identification plan and cut sheet (narrative and table)

This document specifies how cables will be identified for work area cable outlets and telecom rooms. A cut sheet should also be developed listing the data cable runs from the MDF to an IDF and an IDF to at least one work area. The cut sheet should contain room number, connection description or room name, cable ID, cross-connect and port number, cable type, and status for a work area.

6. An IP addressing scheme for all devices on the network (narrative and table)

This is primarily a practice exercise based on the Farb requirements of one subnet per department and one for the common servers. As mentioned in deliverable 1, if this LAN design is done without VLANs, it will require a router per subnet or a powerful centralized router with as many ports as subnets. This exercise is based on the number of departments and not their physical locations and is intended to provide practice on IP addressing and subnetting. Remember to allow for growth.

Optional (extra credit) Documentation

- A cabling plan for the server room
- Equipment purchase costs
- Cabling and testing costs

- Equipment installation costs
- Training and support costs
- Any construction requirements
- Security and fire prevention recommendations for server room, MDFs, and IDF
- Electrical protection for equipment
- A timeline for the implementation of the network

Other factors in the rubric:

In addition to the listed equipment, as specified by the Farb documents, consider the following as additional factors in the rubric:

- Engineering journal - preliminary documentation of user needs, preliminary sketches of cable runs, pinouts, color codes, special safety precautions, and reflections on key points in the installation are some of what might be kept in an engineering journal.
- Problem-solving matrices - a matrix should ideally be created every time there is a choice with several options to be made. Placement of wiring closets, the use of Category 5 versus fiber for a given network segment, and paths to IDFs and MDFs for specific cable runs are all common decisions when doing a structured cabling installation.

Importance should also be given to the following factors:

- Are all required deliverables present?
- Are the deliverables accurate and correct in content?
- Are additional deliverables present, indicating additional effort?
- Is the documentation well organized and presentable, including a table of contents?
- Were both parts of the case study, structured cabling and IP addressing, completed by the required due dates?
- How well did the team work together to achieve their goals?

Case Study Solution

The following pages are examples of documents that would satisfy the requirements of the recommended deliverables for this network design. These are provided with a starting point. These may be modified as necessary. These documents represent one possible solution to the case study and there can be many others that would be equally effective.

1. Recommendations for Network Electronic Equipment

Include all switches, routers with model numbers and locations. Note that equipment type and location can vary depending on network design.

Qty	Item Description	Manufacturer / Model Number	Location	Notes
1	Master Ethernet multilayer switch with two multimode fiber ports (GBIC-based) and 10x 10/100/1000 RJ45 ports.	Cisco 3550-12T	MDF	All edge switches from MDF and IDF connect to this switch using fiber backbone or UTP. Servers can also be connected to this switch.
6	Edge Ethernet switch (24 10/100 RJ45 and 1 multimode fiber GBIC)	Cisco 2950G-24	MDF and IDF-1 and 2	Vertical cable run to Master switch in MDF
1	Internet Router with two Ethernet and 1 Serial WAN ports	Cisco 2621	MDF/POP	Internet Router

2. Recommendations on Cabling and Passive Network Components

Specify cabling types to be used, where they will be used, and why. An estimate of the total required length for each cable type, in meters and feet, should be provided. It should also specify the type and number of patch cables and wall jacks. The type, size, and location of distribution, relay, racks and patch panels, number of ports and so on, should be indicated. It may be desirable to provide two data outlet per work area and one in areas with no workstation, to allow for growth.

Horizontal Cable type

Category 5e cable is to be used for all horizontal cable runs. This is due to its ability to handle speeds up to 1 Gbps at distances of up to 100 meters, 328 feet, and relatively low cost. Switches will provide 100 Mbps to the desktop. Therefore, Cat5e should provide ample room for growth.

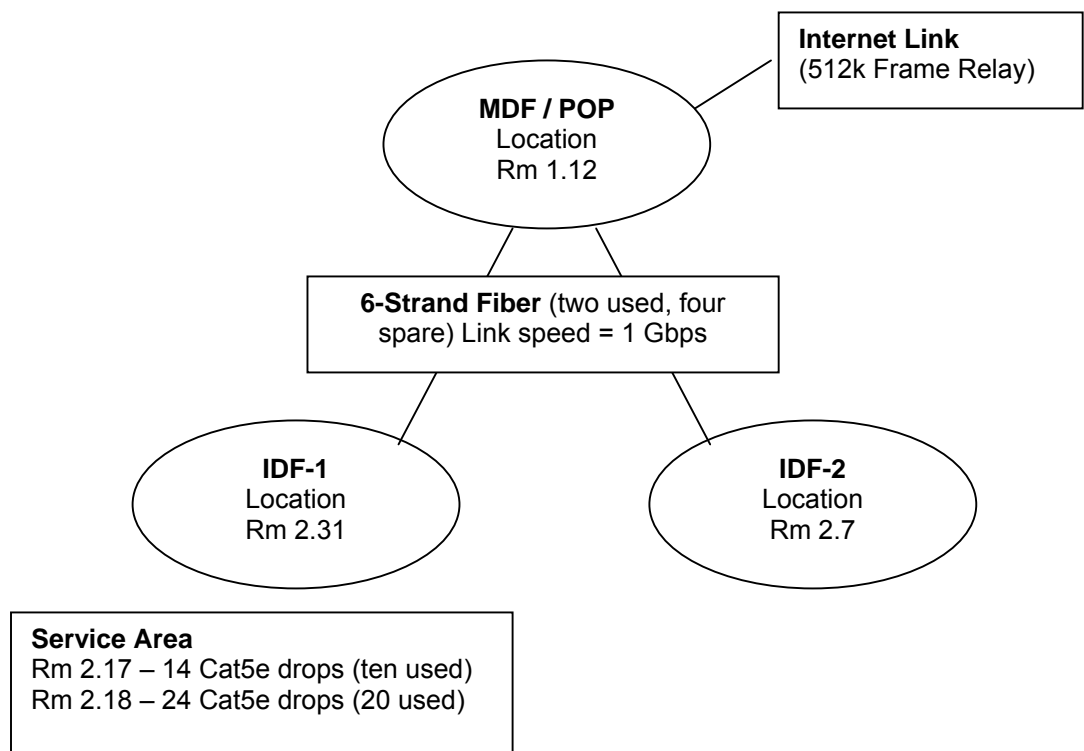
Vertical Cable type

Fiber optic cable is recommended for vertical or backbone cabling in this LAN design, although Cat5e copper could suffice based strictly on the distance between MDF and IDFs. Fiber is chosen due to its superior bandwidth, planned 10 Gbps for future growth, electrical ground isolation characteristic, and resistance to electrical and radio interference.

Qty	Item Description	Manufacturer / Model Number	Location	Notes
15,000 ft (4572m)	Category 5e UTP bulk cable	Belden DataTwist 350 blue	All horizontal cabling	To work areas
150	Category 5e UTP ten foot patch cords	Panduit	Work areas	From wall plate to workstations
150	Category 5e modular wall jacks	Panduit Mini-Com TX5e Jack module	Work area wall plates	From wall plate to workstations, one per work area
4	HCC patch panel	Panduit DP5e 48-port	MDF and IDF	For HCC. one in MDF, two in IDF-1, and one in IDF-2)
3	Distribution or Relay rack	Hubbell 7 ft (84") Relay rack	MDF and IDFs	One in MDF and in each IDF
400 ft (122m)	Multimode bulk fiber cable 62.5/125 Micron	Siecor 6-fiber distribution	MDF and IDFs	One in MDF and in each IDF
3	Multimode fiber patch cable SC-SC 62.5/125 Micron	Siecor 2-fiber	MDF and IDFs	One in MDF and in each IDF
3	VCC patch panel	Siecor 6-pair bulk head	MDF and IDF	One in MDF and in each IDF

3. Horizontal and Vertical Logical Network Layout (diagram)

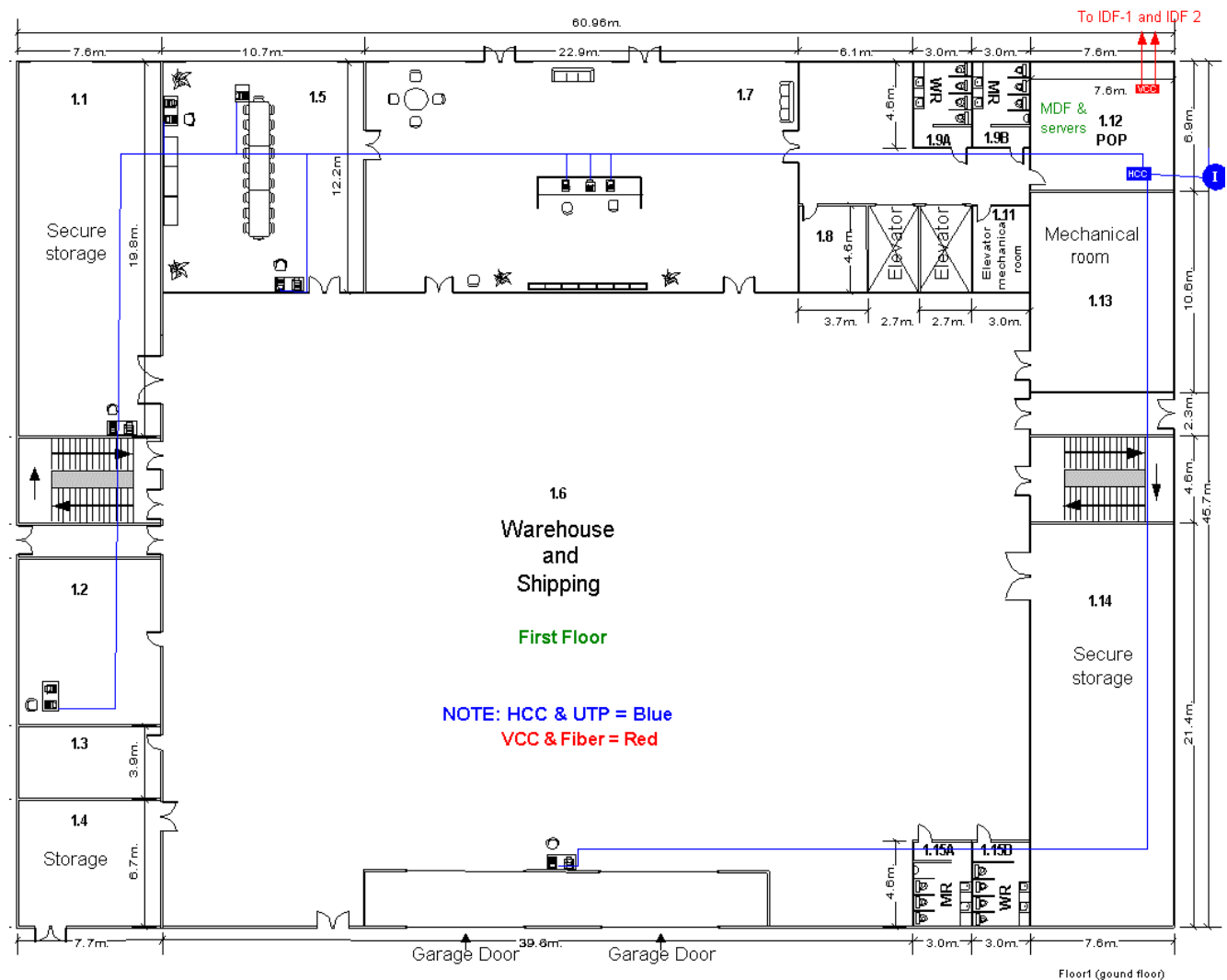
Show the MDF, POP, IDFs, and their logical relationships. Major cable types between these locations should be identified. **Note:** There are multiple locations that might be suitable for the location of the IDFs.



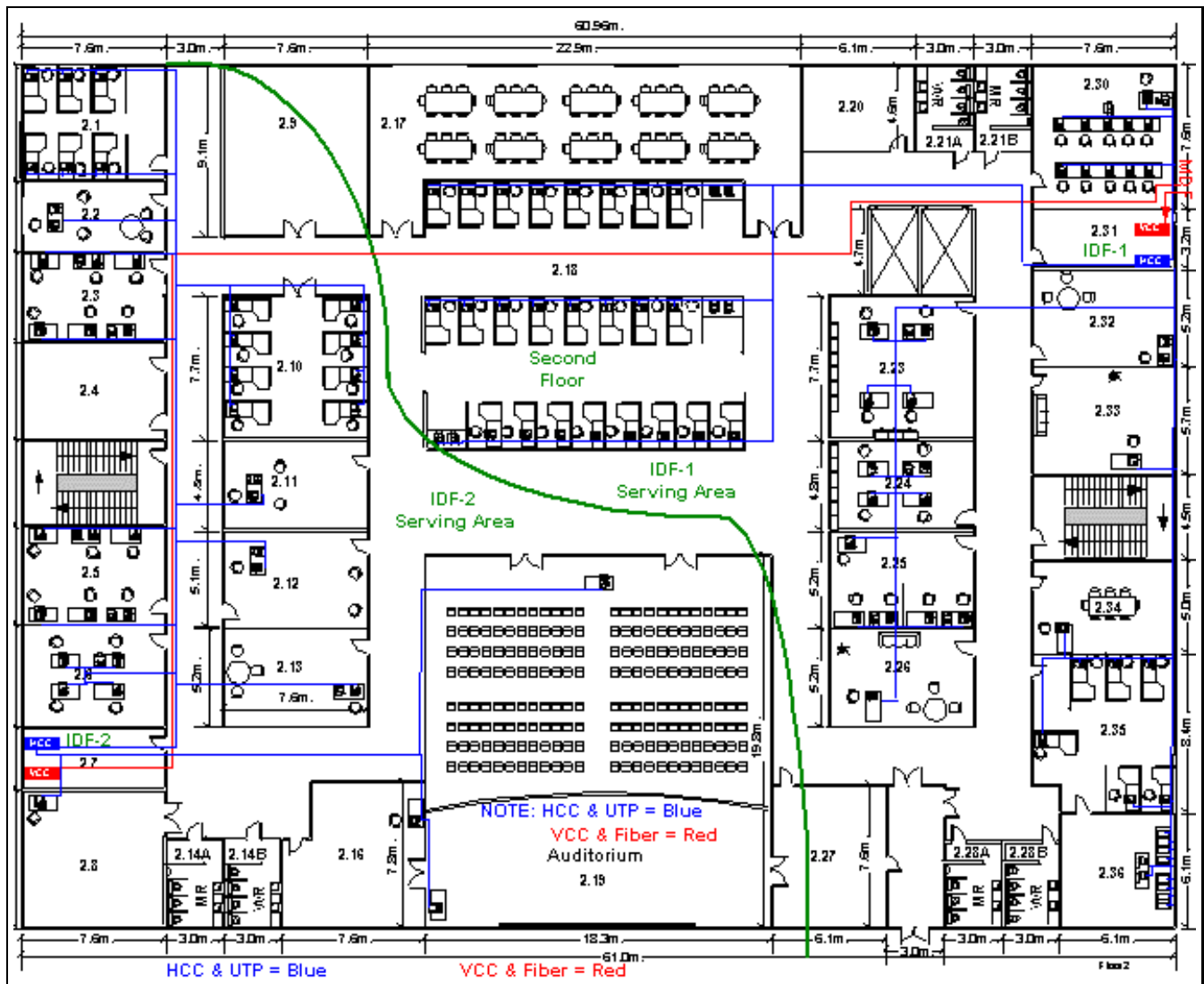
4. Horizontal and Vertical Physical Cable Layout

The layouts are created by marking up the desk location floor plans, showing the MDF and IDF locations, and the cable runs and bundles. Although the MDF will likely be located with the POP on the first floor, there are several potential locations for IDFs. Color-coding should be used to identify MDFs and IDFs. Different colors should be used to indicate Horizontal cross-connects (HCC), with UTP copper cabling, and Vertical cross-connects (VCC), which use fiber cabling.

Note that cable runs will generally follow the cable trays in the ceiling, which are usually aligned with hallways. The exact location of each cable will be determined by the location of the network device it serves and the building structures along its path.



Floor Plan for Floor 1



Floor Plan for Floor 2

5. Cable Identification Plan and Cut Sheet

This document specifies how cables will be identified for work area cable outlets and telecom rooms. A cut sheet should also be developed listing the data cable runs from the MDF to an IDF and an IDF to at least one work area.

Cable and Outlet Identification Labels

All cables shall be labeled at both ends. The label should begin with the source MDF or IDF number followed by the target room number and then a sequence number, for example, I2-2.13-1 is a cable running from IDF-2 to room 2.13, drop #1. All data outlets shall be labeled similarly. If voice cabling shares the same wall plate, an indication must be added to the label to distinguish it from data, for example, I2-2.13-1v.

Cut Sheet

The cut sheet contains room number, connection description or room name, cable ID, cross-connect & port#, cable type, and status for a work area.

The following are two examples:

MDF Cable Runs

The following example shows the cut sheet for the first floor of the Farb building. This includes rooms 1.1 thru 1.7 and cable runs from the MDF to IDF's 1 and 2. It is worthwhile to include rooms that do not have cable runs to account for them. It may also be desirable to run at least one drop to every room, with some exceptions, for flexibility and adaptability.

Room No.	Description	Qty	Cable ID	Cross Connect Number and Port Number	Cable Type	Notes
1.1	Secure Storage	1	M-1.1-1 thru 1	HCC-M-1 / port 1	Cat5e	
1.2	Unassigned	1	M-1.2-1 thru 1	HCC-M-1 / port 2	Cat5e	
1.3	Unassigned	1	M-1.3-1 thru 1	HCC-M-1 / port 3	Cat5e	Not used
1.4	Storage	1	M-1.4-1 thru 1	HCC-M-1 / port 4	Cat5e	Not used
1.5	Conference Rm	3	M-1.5-1 thru 3	HCC-M-1 / ports 5 thru 7	Cat5e	
1.6	Wholesale and Shipping	1	M-1.6-1 thru 1	HCC-M-1 / port 8	Cat5e	
1.7	Product displays	3	M-1.7-1 thru 3	HCC-M-1 / ports 9 thru 11	Cat5e	Not used
MDF	MDF to IDF-1	1	M-2.31-1	VCC-M-1 / Ports 1 and 2	MM fiber	
MDF	MDF to IDF-2	1	M-2.7-1	VCC-M-1 / Ports 3 and 4	MM fiber	

IDF-2 Cable Runs

This example shows a sample from the cut sheet for the second floor of the Farb building. This includes rooms 2.10 thru 2.13.

Room No.	Description	Qty	Cable ID	Cross Connect Number and Port Number	Cable Type	Notes
2.10	Sales Agents	10	I2-2.10-1 thru 10	HCCI2-1 / ports 1 thru 10	Cat5e	2 unused
2.11	Sales Mgr	1	I2-2.11-1 thru 1	HCCI2-1 / port 12	Cat5e	
2.12	Marketing Mgr	1	I2-2.12-1 thru 1	HCCI2-1 / port 13	Cat5e	
2.13	Conf Rm	1	I2-2.13-1 thru 1	HCCI2-1 / port 14	Cat5e	

6. IP Addressing Scheme for Network Devices (table)

This document should identify private and public IP addresses to be used as well as subnet masks and default gateway. It should specify what IP addresses that would be assigned to which devices, such as workstations, servers, switches, and routers. As mentioned in deliverable 1, if this LAN design is done without VLANs, it will require a router per subnet or a powerful centralized router with as many ports as subnets. This exercise is based on the number of departments and not physical locations and is intended provide practice on IP addressing and subnetting. Remember to allow for growth.

External (Public) IP Address: 200.1.1.0

External Subnet mask: 255.255.255.0

Internal (Private) Class A IP Address: 10.0.0.0

Internal (Private) Subnet mask: 255.255.0.0

Department	Subnet Number	Address or Range	Notes
Common Access Servers	10.1.0.0	10.1.1.1 thru 10.1.1.10	These servers are all located in the MDF
Router(s) internal IP addresses	Various subnets depending on how many and where they are located	10.x.1.0, 10.y.1.0, 10.z.1.0 etc.	Can be VLAN interfaces defined in a multilayer switch, interfaces on individual routers, or interfaces on a single router. The internal IP address is the default gateway for devices on a subnet.
Router external IP address	200.1.1.0	200.1.1.1	Internet access public
Switches	Various subnets depending on where they are located	10.x.10.0, 10.y.10.0, 10.z.10.0 etc.	Switches may or may not be assigned IP addresses depending on model and security policies.
Shipping	10.2.0.0	10.2.0.1 – 10.2.0.254	
Tech Support – Ext	10.3.0.0	10.3.0.1 – 10.3.0.254	
Marketing	10.4.0.0	10.4.0.1 – 10.4.0.254	
Sales	10.5.0.0	10.5.0.1 – 10.5.0.254	
Accounting	10.6.0.0	10.6.0.1 – 10.6.0.254	
Tech Support – Int	10.7.0.0	10.7.0.1 – 10.7.0.254	
Software development	10.8.0.0	10.8.0.1 – 10.8.0.254	
Unassigned	10.9.0.0	10.9.0.1 – 10.9.0.254	
Unassigned	10.10.0.0	10.10.0.1 – 10.10.0.254	
Unassigned	10.11.0.0	10.11.0.1 – 10.11.0.254	
Unassigned	10.12.0.0	10.12.0.1 – 10.12.0.254	

V. Appendices:

- A) Cisco Online Tools and Utilities
- B) Instructional Best Practices

Appendix A: Cisco Online Tools and Utilities

Cisco Systems offer a wide range of online documents and tools to assist in configuring, troubleshooting, and optimizing routers and switches. The Cisco Technical Assistance Center (TAC) website (<http://www.cisco.com/en/US/support/index.html>) is a section on cisco.com which provides these resources. To learn more about the Cisco TAC website visit http://www.cisco.com/public/news_training/tac_overview.html. This document introduces ten valuable resources available to users at cisco.com.

Accessing all of the tools on the Cisco TAC website requires a cisco.com user ID and password. Obtain a user ID and password with a valid Cisco service contract at <http://tools.cisco.com/RPF/register/register.do>.

1. Output Interpreter

The screenshot shows the Cisco Systems website's Technical Support section. The 'Tools & Utilities' menu is expanded, highlighting the 'Output Interpreter' tool. A yellow callout box explains a new feature: pasting PIX show tech-support or running configuration into the tool to automatically convert 'condult', 'outbound' or 'apply' statements to 'access-list' statements. Below this, a paragraph describes the tool's purpose: reporting potential problems by analyzing supported show command output. It provides links to an 'example of results generated' and a 'List of Supported "Show" Commands'. A second link, 'Problem to Command Mappings', is also present. The main form area is titled 'Enter "show" command(s) output from your device for analysis.' and includes a note to remove passwords. It features a large text area for pasting output, a 'View Output Example' link, and a 'Browse...' button for uploading files larger than 30K. The right sidebar contains a search bar, a 'Toolkit' section with icons for various tools, and a 'Related Tools' section with links to 'TAC Case Open', 'Command Lookup Tool for Cisco IOS', and 'Bug Toolkit'.

CISCO SYSTEMS Home | Logged In | Profile | Contacts & Feedback | Help | Site Map

Technical Support Select a Location / Language

TECHNICAL SUPPORT + TOOLS & UTILITIES

TOOLS & UTILITIES +

▼ Output Interpreter

Output Interpreter

Check out this new functionality! Now you can paste your PIX show tech-support or running configuration into Output Interpreter to automatically convert 'condult', 'outbound' or 'apply' statements to 'access-list' statements.

The Output Interpreter is a troubleshooting tool that will report potential problems by analyzing supported show command output. View an [example of results generated](#) by this tool.

Not all commands are supported by Output Interpreter. Look up supported commands relevant to your issue in the following lists:

- [List of Supported "Show" Commands](#): The list of commands the Output Interpreter can analyze, and information on the analysis.
- [Problem to Command Mappings](#): Recommended command(s) to submit to troubleshoot the issue you are experiencing.

Enter "show" command(s) output from your device for analysis.
Remove passwords and other sensitive information.

Paste the output of your command(s) in the field below: [View Output Example](#)
(Note: You can paste multiple command outputs in the field below.)

Or, for output larger than 30K, click the Browse button to upload a file.
Enter a file name (or browse your disk):

Search:
Search All Cisco.com

Toolkit: Roll over tools below
[Feedback](#) | [Help](#)

Related Tools
[TAC Case Open](#)
[Command Lookup Tool for Cisco IOS](#)
[Bug Toolkit](#)

Output Interpreter is a web-based application. It allows instant access to troubleshooting analysis and a course of action for a router, switch or PIX device using collected show command output. Paste in the output of one or a set of the supported commands to receive a report including errors, warnings, and relevant troubleshooting information. The report also includes crash analysis and error message decodes, which were previously supported by the Stack Decoder and the Error Message Decoder tools (requires CCO ID and password).

<https://www.cisco.com/cgi-bin/Support/OutputInterpreter/home.pl>

2. Error Message Decoder

The screenshot shows the Cisco Error Message Decoder web page. At the top, there is a Cisco Systems logo and a navigation bar with links: Home, Logged In, Profile, Contacts & Feedback, Help, and Site Map. Below the navigation bar is a search bar with a 'GO' button. The main content area is titled 'Error Message Decoder' and contains the following text:

This tool will help you research and resolve error messages for Cisco IOS Software, Catalyst Switches Software, and Cisco Secure PIX Firewall Software. Follow the steps below to receive a description, recommended action, and related resources for your one- or two-line error message.

Standard error messages have the following structure :
%FACILITY-SEVERITY-MNEMONIC : Message-text (Ex: %SYS-2-MALLOCFAIL).

Other console messages (like debugs or router crashes) are not supported by this tool. Please check the [help](#) file for more information.

Copy the error message from your device, paste it here, then click Submit.

Paste Error Message:

☒ suggest related documents within results

On the right side, there is a 'Search:' section with a search bar and a 'GO' button. Below this is a 'Toolkit:' section with a 'Roll over tools below' label and icons for Feedback and Help. At the bottom, there is a 'Related Tools' section with links: TAC Case Open, TAC Case Query, and Output Interpreter.

At the bottom of the page, there is a footer with links: BUSINESS INDUSTRIES & SOLUTIONS | NETWORKING SOLUTIONS | PRODUCTS & SERVICES | TECHNOLOGIES | ORDERING | TECHNICAL SUPPORT | LEARNING & EVENTS | PARTNERS & RESELLERS | ABOUT CISCO. Below these links is a copyright notice: © 1992-2003 Cisco Systems, Inc. All rights reserved. Important Notices, Privacy Statement, and Trademarks of Cisco Systems, Inc.

Look up explanations for console error message strings listed in the Cisco Software System Messages guide (requires CCO ID and password).

<http://www.cisco.com/cgi-bin/Support/Errordecoder/home.pl>

3. Software Bug Toolkit

The screenshot shows the Cisco Software Bug Toolkit web interface. At the top left is the Cisco Systems logo. A 'Close Window' link is in the top left corner. In the top right corner, there is a 'Toolkit: Roll over tools below' menu with icons for Feedback, Help, and a search icon. Below the header is a yellow bar with the text 'Bug Toolkit'. The main content area has a 'SEARCH' tab and a 'MY STUFF' tab. Under the 'SEARCH' tab, there is a section titled 'Select one of these options'. The first option is 'Enter known bug ID:' with a text input field and a 'Search' button. Below the input field is a hint: '(example: CSCdp94390)'. The second option is 'Search for Cisco IOS-related bugs by release.' with a 'Next' button. Below this is a link: 'Click here for products running Cisco IOS. This includes routers, Catalyst and GSR/12000. (To verify that you are running Cisco IOS, type 'show version' in enabled mode and look for the following: 'Cisco Internetwork Operating System Software')'. The third option is 'Search for bugs in other Cisco software and hardware products' with a 'Next' button. Below this is a text input field with the placeholder 'Type your product name here' and a list of products: ART, ATM PCI-bus, ATM S-bus, BAT, C5K-GEM, CDN Software Service Provider Edition, CWSI Campus, and Cisco 181 Analog Telephone Adaptor. A 'Next' button is also present. At the bottom left is a 'Close Window' link. At the bottom right is a copyright notice: '© 1992-2003 Cisco Systems, Inc. All rights reserved. Important Notices, Privacy Statement, and Trademarks of Cisco Systems, Inc.'

There are times when a certain feature does not work. Software Bug Toolkit is a web resource, which allows for the search of software bugs based on version and feature sets (requires CCO ID and password).

http://www.cisco.com/cgi-bin/Support/Bugtool/launch_bugtool.pl

4. IP Subnet Calculator

The screenshot shows the Cisco IP Subnet Calculator web page. At the top, there is a Cisco Systems logo and a navigation bar with links: Home, Logged In, Profile, Contacts & Feedback, Help, and Site Map. Below the logo is a 'Technical Support' dropdown menu with a 'GO' button. A search bar is located on the right side of the header. The main content area is titled 'IP Subnet Calculator' and features four tabs: HOME, SUBNETS, SUPERNETS (CIDR), and VLSM. The 'HOME' tab is currently selected. The text under the 'HOME' tab reads: 'This tool provides a way to calculate IP subnetting which is fast, easy, and error free. Choose a function by clicking below or by selecting one of the tabs above.' Below this text are three links: 'Subnets', 'Supernet (CIDR)', and 'VLSM'. Each link has a brief description of its function. On the right side of the main content area, there is a 'Search' bar, a 'Search All Cisco.com' dropdown, and a 'Toolkit' section with icons for various tools. At the bottom of the page, there is a footer with links to 'BUSINESS INDUSTRIES & SOLUTIONS', 'NETWORKING SOLUTIONS & PROVISIONED SERVICES', 'PRODUCTS & SERVICES', 'TECHNOLOGIES', 'ORDERING', 'TECHNICAL SUPPORT', and 'LEARNING & EVENTS'. The footer also includes a copyright notice: '© 1992-2003 Cisco Systems, Inc. All rights reserved. Important Notices, Privacy Statement, and Trademarks of Cisco Systems, Inc.'

IP Subnet Calculator is a web-based resource where the subnet mask can be calculated based on several variables. Use this tool to verify network settings (requires CCO ID and password).

<http://www.cisco.com/cgi-bin/Support/IpSubnet/home.pl>

5. Password Recovery Procedures

[Solutions](#) [Products](#) [Ordering](#) [Support](#) [Partners](#) [Training](#) [Corporate](#)
Tech Notes

Password Recovery Procedures

Document ID: 6130

Please provide your [feedback](#) on this document.

This page is the index of password recovery procedures for Cisco products.

Note: For security reasons, the password recovery procedures described here require physical access to the equipment.

High-End Routers

Cisco 12000 Series Routers	Cisco 7100 Series Routers	Cisco uBR7200	Cisco AGS
Cisco 7000 Series Routers	Cisco uBR7100	Cisco 7500 Series Routers	Route Processor Module
Cisco 7000 Series Route Switch Processor (RSP7000)	Cisco 7200 Series Routers	Cisco uBR10000	

LAN Switches

EtherSwitch/FastSwitch/FastHub	Catalyst 2100 Series Switches	Catalyst 2950 Series Switches	Catalyst 5500/5000/2926G/2926 Series Switches
Catalyst 1200 Series Switches	Catalyst 2600 Series	Catalyst 3000/3100/3200	Catalyst 6000 Series

This Web page is the single source for Cisco password recovery procedures. Password recovery procedure for every Cisco device is located here.

<http://www.cisco.com/warp/public/474/>

6. TAC Case Collection

The screenshot shows the Cisco Systems Technical Support website. The header includes the Cisco logo, navigation links (Home, Logged In, Register, Contacts & Feedback, Help, Site Map), and a search bar. The main content area is titled 'TECHNICAL SUPPORT' and 'TAC Case Collection'. It provides an overview of the TAC Case Collection tool, which helps users identify and troubleshoot common networking problems. A note specifies that the tool supports browser versions IE 5.5 and later or Netscape 6.x and later. The page lists several categories of support, each with a brief description and a 'NEW!' badge:

- ATM Media Support**: ATM link level access
- Dial (Access)**: DDR & non-DDR callout using external modem, CAS T1/E1, PRI, or BRI, Local and AAA server based authentication and authorization, LCP and NCP negotiations, authentication failure, link stability, and routing packets
- Frame Relay**: PVCs, SVCs, Traffic Shaping, dial-backup, PPP over Frame Relay, configuration, performance and connectivity issues
- IP Routing Protocols**: Common issues on configuration, routes missing from routing table, route not being redistributed, network not being advertised, neighbor not forming or flapping, Internet and network connectivity, NAT, PBR, HSRP and error messages. Routing protocols covered include EIGRP, OSPF, BGP and RIP
- LAN Switching**: Configuration, connectivity, VLANs, trunking, autonegotiation, passwords and catalyst hardware issues
- Hardware Troubleshooting**: Catalyst switches (2900XL, 3500XL, 2948G-L3/4908G-L3, 4000/4912G/2980G/2948G, 5000/5500/2926G/2926, 6000/6500), MSFC/MSFC2, access servers (AS5200/5300, AS5350/5400, AS5800), and MC3810 Access Concentrator
- Router and IOS Architecture**: Router crashes, upgrades, installation, password recovery, error messages, memory, hardware, and booting problems for Cisco routers (800, 1600, 2500, 2600, 3600, 3700, 4000, 4500, 4700, 7200, uBR 7200 & 7500), modules (7500 RSP, VIP, FEIP & GEIP), and access servers (AS5200, AS5300 & AS5800)
- Security**: Connectivity, hardware, software features and upgrades, licensing, password recovery for the PIX and VPN 3000 Concentrator, and VPN client installation

On the right side of the page, there is a search bar, a 'Toolkit' section with links to 'Roll over tools below', 'Feedback', and 'Help', and a 'Related Tools' section with links to 'TAC Case Open', 'TAC Case Query', and 'Error Message Decoder'.

The TAC Case collection is an evolution of the Troubleshooting Assistant tool. It helps interactively identify and troubleshoot common problems involving hardware, configuration, and performance issues. These solutions, provided directly by TAC engineers, resolve actual networking problems (requires CCO ID and password).

http://www.cisco.com/kobayashi/support/tac/tsa/launch_tsa.html

7. Software Advisor

The screenshot shows the Cisco Software Advisor web application. At the top, there is a Cisco Systems logo and a 'Close Window' button. A 'Toolkit: Roll over tools below' section contains icons for a menu, email, a plus sign, and a document, with 'Feedback' and 'Help' links below them. The main navigation bar has three tabs: 'HOME', 'SOFTWARE SUPPORT FOR FEATURES', and 'SOFTWARE SUPPORT FOR HARDWARE'. The 'HOME' tab is active. The content area starts with a prompt: 'Want to try out what's new in Software Advisor? If you have one of the following supported products: Switch Series: 4000, 4500, 5000, 5500, 6000, 6500'. Below this is a link: '....You can [try it now.](#)'. A paragraph follows: 'For each entry point below, you have the option to search for applicable software bugs using the Bug Toolkit.' There are two main sections: 'Software Support for Features:' and 'Software Support for Hardware:'. The 'Features' section includes links for 'Search by Features' (create a list of Cisco IOS or CatOS features), 'Search by Release' (select your Cisco IOS or CatOS release), and 'Compare Releases' (select two Cisco IOS releases). The 'Hardware' section includes links for 'Cisco IOS, PIX OS, or WAN Switching Supported Hardware' (create a list of hardware products) and 'CatOS Supported Hardware' (populate your Catalyst chassis with CatOS hardware). A 'Note' states: 'The Catalyst 4000, 5000, and 6000 Series have both Cisco IOS and CatOS supported hardware.' At the bottom, there is a 'Close Window' button and a copyright notice: '© 1992-2003 Cisco Systems, Inc. All rights reserved. [Important Notices](#), [Privacy Statement](#), and [Trademarks](#) of Cisco Systems, Inc.'

Choose appropriate software for a network device. Match software features to Cisco IOS and CatOS releases, compare IOS releases, or find out which software releases support this hardware (requires CCO ID and password).

<http://www.cisco.com/cgi-bin/Support/CompNav/Index.pl>

8. Feature Navigator II

The screenshot shows the Cisco Feature Navigator II web application. At the top, there is a Cisco Systems logo and a navigation bar with links for Home, Logged In, Profile, Contacts & Feedback, Help, and Site Map. Below the navigation bar, there is a search bar with the text "Products & Services" and a "GO" button. The main content area is titled "CISCO IOS SOFTWARE" and "Cisco Feature Navigator II". It includes a sidebar with a tree view of products and services, a search bar, and a "Toolkit" section with links to various tools. The main content area contains a section titled "What Took Hours Now Takes Minutes" which describes the application's purpose. It also includes sections for "Navigate Cisco IOS software release by searching on", "Feature", "Release", "Compare Releases", and "Learn About Release 12.3: Easy Access to Voice, Security, and QoS". A "Cisco IOS SOFTWARE RELEASE 12.3T" banner is visible in the bottom right corner.

CISCO IOS SOFTWARE
Cisco Feature Navigator II

What Took Hours Now Takes Minutes
Cisco Feature Navigator is a web-based application that allows you to quickly find the right Cisco IOS Software release for the features you want to run on your Network.

Navigate Cisco IOS software release by searching on

Feature: Quickly find which Cisco IOS release supports your features (IP, BGP, etc....).
[Search by feature](#)

Release: Quickly find the features in your Cisco IOS releases or platforms.
[Search by Release/Image Name/Product Code/Platform](#)

Compare Releases: Quickly Compare between two Cisco IOS releases.
[Compare Images](#)

Learn About [Release 12.3](#): Easy Access to Voice, Security, and QoS.

Feature Navigator NOW supports all the major Cisco IOS releases.
By using this tool, you agree to all of Cisco System's [terms and conditions](#) for this tool.

CISCO IOS SOFTWARE RELEASE 12.3T

Cisco Feature Navigator II is a web-based application that allows the right Cisco IOS Software release for the features that are to be run on the network to be located quickly. The search may be done by feature, release, or even compare two different releases (requires CCO ID and password).

<http://www.cisco.com/go/fn>

9. TAC Advanced Search

CISCO SYSTEMS Home | Logged In | Register | Contacts & Feedback | Help | Site Map

Technical Support

TECHNICAL SUPPORT **TOOLS & UTILITIES**

TAC Advanced Search

New! The Cisco.com search can perform many of the same functions as the TAC Advanced Search. [More info](#)

Look in:

☒ [TAC Technical Documentation](#) ☐ all of [www.cisco.com](#)

☐ [TAC Data Collections](#) ☐ [NetPro search](#)

Find:

(use one or more of these fields)

with **all** of the words

with the **exact phrase**

with at **least one** of the words

without the words

Type of File:

☒ All TAC Document Types ☐ Password Recovery

☐ Case Studies ☐ QandAs

☐ Configuration Examples ☐ Security Advisories

☐ Field Notices ☐ Tech Notes

☐ Networking Solutions ☐ White Papers

Results per page:

☒ 10 ☐ 25 ☐ 100

Search:

Toolkit: Roll over tools below

[Feedback](#) | [Help](#)

Related Tools

[Service Contract Center \(SCC\)](#)

[Networking Professionals Connection](#)

Related Links

[Products & Services](#)

[Technical Support Services Introduction](#)

Learning & Events

[TAC Training Resources](#)

Technologies

[Report Product Security Incident](#)

Manage your TAC Cases

[Open a case](#)

[Query a case](#)

Access the same resources the TAC uses. Search the entire TAC database for technical documents written by the Cisco TAC, for TAC Technical Support Tools, for documents located on cisco.com, or for entries in the Networking Professionals Connection discussion forums.

http://www.cisco.com/kobayashi/support/tac/s_tac.shtml

Appendix B: Instructional Best Practices

B.1 Definitions of Best Practices

B.1.1 What is meant by “best practices”?



Figure 1: Best Practices

Since the early 1980s, schools have been exploring with the use of technology as an effective tool for teaching and learning in the classroom. Current research speaks clearly about certain practices and strategies that help teachers maximize student learning. Certain instructional concepts, such as student centered learning and brain compatible learning, have surfaced as powerful contributors to higher student achievement. These techniques, among many others, are referred to as “best practices”.

The Academy teaching and learning community consists of over 20,000 instructors. Each instructor brings experiences and talents to the program. This chapter is meant to present options, which have been found useful for certain audiences and certain topics. It is not meant to say all of these techniques apply equally well to all students in all curricula. The Academy Program includes CCNA, CCNP, Fundamentals of UNIX, Fundamentals of Voice and Data Cabling, Fundamentals of Java, Fundamentals of Web Design, and IT Essentials. Cisco believes that with the range of Academy IT curriculum, these best practices establish the most effective teaching and learning environments.

The ideas presented in this chapter are taken from international sources such as kindergarten through high school, community colleges, university teaching environments, instructional design and training models, and the IT teaching community.

Web Links

International Society for Technology in Education

<http://www.iste.org/>

Southeast Center for Teaching Quality

<http://www.teachingquality.org/>

Milken Family Foundation

<http://www.mff.org/>

North Central Regional Educational Laboratory

<http://www.ncrel.org/>

Alabama Best Practices Center

<http://www.bestpracticescenter.org/index.asp>

Mid-Continent Research for Education and Learning

<http://www.mcrel.org/>

B.1.2 NETS

NETS Standards
<ul style="list-style-type: none">• National Educational Technology Standards for Students (NETS)• National Educational Technology Standards for Teachers (NET•T)• National Educational Technology Standards for Administrators (NET•A)

Figure 1: NETS Standards

The International Society for Technology in Education (ISTE) is a nonprofit professional organization dedicated to preparing students, teachers, and administrators for a working world that demands proficiency in information technology. The ISTE has written National Educational Technology Standards (NETS) for students, teachers, and administrators. The National Educational Technology Standards for Students are divided into the following six categories:

1. Basic operations, and concepts
2. Social, ethical, and human issues
3. Technology productivity tools
4. Technology communication tools
5. Technology research tools
6. Technology problem-solving and decision-making tools

ISTE also features the National Educational Technology Standards for Teachers (NETS•T). There are six categories for teacher standards based upon current research on teaching and learning with technology. The ISTE has taken into consideration the need for planning and integration as well as the emergence of new technologies in the classrooms of today. The six categories are as follows:

1. Technology operations and concepts
2. Planning and designing learning environments and experiences

3. Teaching, learning, and curriculum
4. Assessment and evaluation
5. Productivity and professional practice
6. Social, ethical, legal, and human issues

For administrators, the ISTE has developed the National Educational Technology Standards for Administrators (NETS•A). Administrators must be prepared to lead the way to systemic reform. Based upon a national consensus, a recognized set of indicators is in place within school systems that are utilizing technology effectively. The following are six categories for strong leadership in the area of information technology:

1. Leadership and vision
2. Learning and teaching
3. Productivity and professional practice
4. Support, management, and operations
5. Assessment and evaluation
6. Social, legal, and ethical issues

Web Links

ISTE Website

<http://www.iste.org/>

B.1.3 Literacy, math, and science standards

States and school districts across the United States, have elevated the importance of raising standards in core subjects. States have begun to use academic standards to clearly identify what students should learn and what teachers should teach. State and local standards keep the education system accountable for results in student achievement.

With state standards gaining momentum, educators have gradually generated agreement about the meaning of two significant concepts, academic content standards and performance standards, which were later published in the Goals 2000 Act.

Educational standards are also very important across the world. The Academy Program works on a region-by-region, country by country, curriculum-by-curriculum basis to achieve alignment with international educational standards.

Web Links

National Council for Teachers of English

<http://www.ncte.org/standards/standards.shtml>

Council for Teachers of Math

<http://www.nctm.org/>

National Science Teachers Association

<http://www.nsta.org/>

American Association for the Advancement of Science

<http://www.aaas.org/>

The National Academy of Science

<http://www.nas.edu/>

National Research Council (NRC)

<http://www.nrc-cnrc.gc.ca/>

B.1.4 TIMSS report

Participating Countries		
Australia	Indonesia	New Zealand
Belgium (Flemish)	Iran, Islamic Republic	Phillippines
Bulgaria	Israel	Romania
Canada	Italy	Russian Federation
Chile	Japan	Singapore
Chinese Taipei	Jordan	Slovak Republic
Cyprus	Korea, Rep. of	Slovenia
Czech Republic	Latvia (LSS)	South Africa
England	Lithuania	Thailand
Finland	Macedonia, Rep. of	Tunisia
Hong Kong, SAR	Malaysia	Turkey
Hungary	Moldova	United States
	Morocco	
	Netherlands	

Figure 1: TIMSS Report Participating Countries

The Third International Mathematics and Science Study (TIMSS) gives a good indication of how students in the United States are achieving academically in comparison to students in other countries. The curriculum focus looks at trends in math and science achievement. The study completed in 1995 discovers that fourth grade U.S. students scored above the international average. For eighth graders, the United States scored above the international level in science but below the international level in mathematics. For twelfth graders, the United States scored at the lowest possible levels in both math and science.

Two findings become clear when types of knowledge presentation are compared internationally. First, the United States leads the world in the amount of math and science objectives covered within curriculum, but they tend to fall short of teaching students how to use what they are learning. Asian nations and European nations may teach fewer objectives, but they give students more opportunities to use that knowledge in real world applications. Secondly, this study finds dissimilarity in style of teaching. For students in the United States, problem-solving usually takes place after the teacher demonstrates the process to find the correct answer based upon mathematical principals. Then students will apply problem-solving skills to other similar mathematical problems, following the initial example demonstrated by the teacher. In other countries like Japan, the order of methodology is reversed. Problem-solving comes first in the sequence of learning. Students are presented with a problem and spend time trying to solve the problem based on their current understandings.

They invent their own solutions and then reflect on the process to better their understanding of mathematical concepts. This study forces educators to reflect upon teaching practice as well as content in hopes of determining best methods that will lead to higher student achievement.

The most recent implementation of this study is TIMSS 1999 which included 38 countries. The 1999 assessment measured the mathematics and science achievement of 13 and 14 year-old eighth grade students. Extensive data was collected from students, teachers, and school principals about mathematics and science curricula. They also investigated instructional practice, home contexts, school characteristics, and policies. The next TIMSS assessment will take place in 2003.

Web Links

Third International Math and Science Study

<http://isc.bc.edu/timss1999benchmark.html>

TIMSS International Study Center

<http://timss.bc.edu/>

B.1.5 Student-centered learning

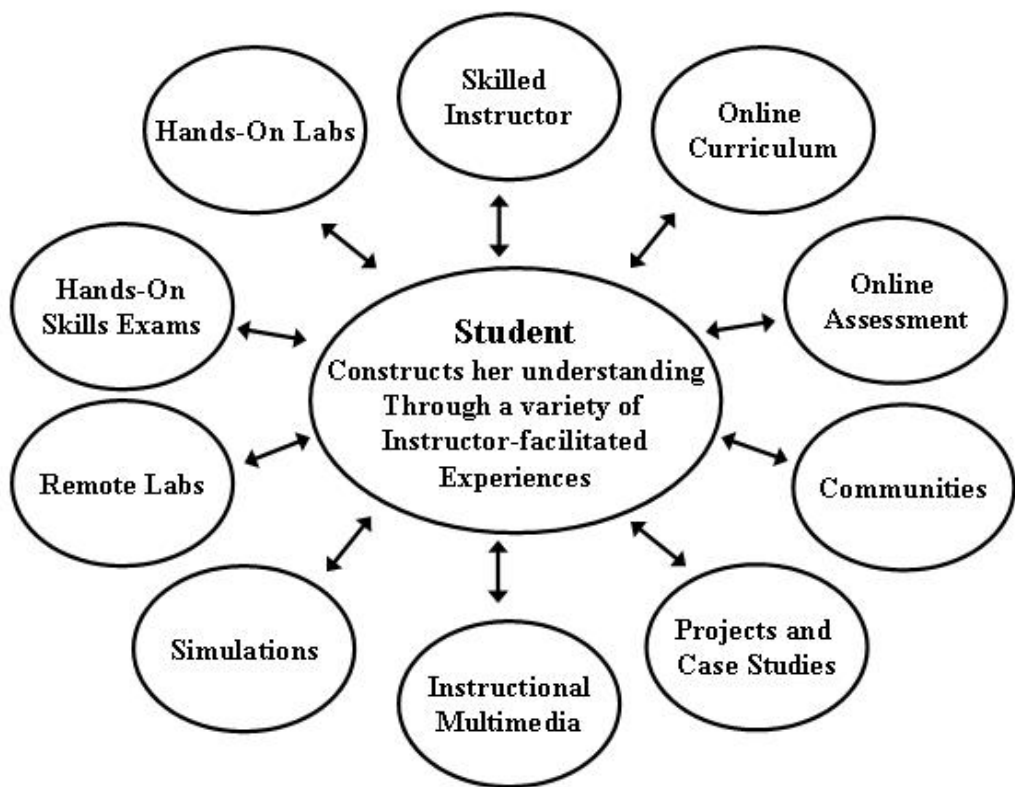


Figure 1: Learner Model: Academy Student

The diagram shown illustrates one representation of the learning process. How can Cisco attain high achievement for all Academy students through teaching and learning practices? One thought is to use each spoke on this diagram and ask, "How can the Academy Program, online curriculum and labs, and the instructor strengthen and enhance each area?"

When all components of the diagram are in place, research states that students are successful in their learning. This model can be said to represent a "constructivist learning" approach.

Constructivist learning comes from the word construct, which comes from the Latin word constructus, which means to build. The Cisco Networking Academy is all about students building knowledge to use in the real world. Constructivist learning is also known as student-centered learning. It is recognized as an exemplary Instructional Best Practice in the educational world. This method of teaching places students in control of their own learning as they practice skills for experimentation, inquiry, problem-solving, decision-making, and communication. Constructivist learning can take place on an individual level, in paired groupings of two students, or in small cooperative groups of three or four students.

During constructivist activities, an essential question is presented to an individual or a group for thoughts and discussion. If students work as a team, they can find information about issues that surface during their discussion time. As a team, students assign roles and identify jobs that need to be completed for the benefit of the whole group. Ultimately, they take their current understanding and gather new understandings through a continuous cycle of inquiry and exploration. Individuals go through the same process but without team direction and input. Students are actively involved in making their own decisions about the relevancy of information. They use their peers and other data sources to make decisions about what information is most useful.

During this time, the instructor assumes a role that is much different from teaching skills and knowledge. The instructor becomes a facilitator of learning. As students examine their questions and passion for learning, teachers ask essential questions to further thinking and exploration. As students struggle with challenges, teachers model problem-solving strategies and encourage students to keep working with what is perceived as a difficult situation. As students master content, teachers take them to the next level of challenge.

Web Links

Pedagogical Application of Technology: A Consortium for Change:

<http://courses.temple.edu/ta/constructivist.htm>

B.1.6 Multiple intelligences

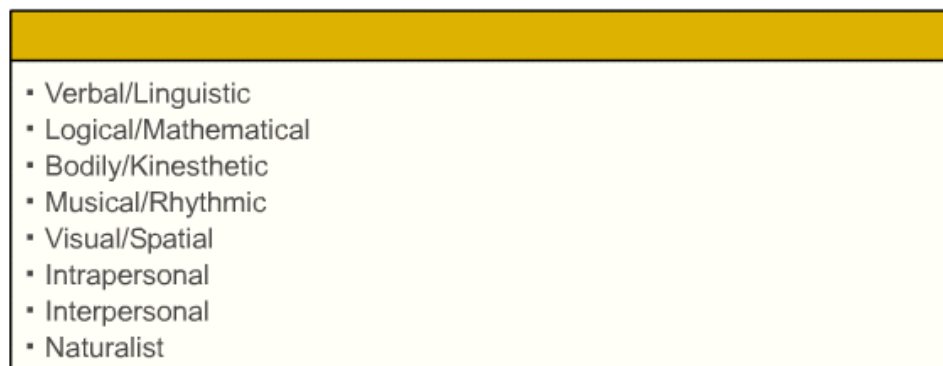


Figure 1: Multiple Intelligences

The research of Howard Gardner gives great insight into how students learn. It is known that not all students learn in the same way. There are multiple intelligences that go beyond the traditional verbal and mathematical abilities depended upon to help in mastering new learning.

According to Gardner, the following are the eight intelligences that people have a predetermined strength to use:

1. Verbal/Linguistic intelligence allows students to understand verbal and written forms of words. Students with strong verbal/linguistic intelligence easily recognize sounds, languages, and inflections of speech.
2. Logical/Mathematical intelligence allows students to understand and interact with numbers, symbols, and patterns, especially found within the disciplines of math and science.
3. Bodily/Kinesthetic intelligence gives students a strong connection to new content through the movement and manipulation of body and external objects. Activity helps students to create cognitive connections for easy recall and comprehension.
4. Musical/Rhythmic intelligence centers on melody, tune, pitch, rhythm, and patterns found in types of music or cadence. For some students, music presents an environment that fluctuates from peaceful to highly energetic. Their brains respond accordingly and understanding or recall of new information becomes tied to remembering or hearing a specific rhythm or cadence.
5. Visual/Spatial intelligence centers on the ability to recognize and respond to visual content through the written word or artistic design. Having visual/spatial strength helps students interpret maps and charts as well as form mental images of information communicated by another person.
6. Intrapersonal intelligence provides a confidence in self that allows a student to process new information through thought and reflection. Having a strong intrapersonal intelligence means having a strong personal connection to feelings and emotions, which can take a student to a higher level of consciousness toward learning.
7. Interpersonal intelligence allows a student to accurately perceive the emotions, feelings, motivations, and intentions of others. A student with strength in this intelligence lends to a strong team player mentality. A student with this strength will work thoughtfully within group settings.
8. Naturalist intelligence grants recognition of natural phenomenon such as flora and fauna, soil and land, and weather and environmental issues. These students easily make choices on everything from survival in the wild issues to selecting proper clothing for different weather conditions.

Gardner's research states that all individuals have strength in one or more of these intelligences and they will follow a changing pattern of strength depending on stages of human life and circumstance. In order for student achievement to be maximized, the Cisco Networking Academy Program encourages instructors to tap into the intelligence that best reflects the learning style of individual students.

Web Links

Project Zero

<http://www.pz.harvard.edu/>

B.1.7 Inquiry-based learning

KWHLAQ
<ol style="list-style-type: none">1. What do we think we Know about the subject?2. What do we Want to find out about the subject?3. How are we going to go about finding our answers?4. What do we anticipate Learning? What have we learned?5. Can we Apply our learning to other subjects or projects?6. What new Questions have surfaced through out time of inquiry?

Figure 1: Inquiry Based Learning

When people uncover phenomena in life that appears uncertain, curious, or just plain interesting, questions naturally surface that in turn launch quests for answers. Inquiry is a natural process that begins as soon as a child starts to experiment with language. As questions are asked, the answers that are found sometimes lead to more questions. A cycle of inquiry for learning begins. In education, instructors know this process as "Inquiry-based Learning" or "Problem-based Learning". The basic requirements of either practice are strong pre-reading skills and good scientific observation techniques. One methodology for inquiry-based learning is called KWHLAQ, which asks the following questions:

1. What do we think we **K**now about the subject?
2. What do we **W**ant to find out about the subject?
3. **H**ow are we going to go about finding our answers?
4. What do we anticipate **L**earning? What have we learned?
5. Can we **A**pply our learning to other subjects or projects?
6. What new **Q**uestions have surfaced through our time of inquiry?

Within any inquiry-based learning activity or project, the range of control must remain flexible. There will be times when the instructor takes control of the learning environment, times when the student exercises more independence, and times when instructor and student share the direction for learning. The instructor role is always that of role model for life-long learning. Through modeling, instructors show students that even instructors address problems on a daily basis in and out of school. They also model the fact that sometimes problems are solved successfully and sometimes not so successfully. It becomes clear to students that essential questions often require a team approach to find the solution to big problems. Students and the instructor working together become that team.

Web Links

Big Rocks and Powerful Kingdoms Personal Learning in Science and Social Studies:

<http://ascd.org>

Using the Internet to Promote Inquiry-based Learning:

<http://www.biopoint.com/msla/links.html>

Project Based Learning: What is it?:

<http://www.4teachers.org/projectbased/>

B.1.8 Special needs

Special Needs
<ul style="list-style-type: none">• Visually impaired• Hearing impaired• Physically impaired

Figure 1: Special Needs

When there are visually impaired students in a classroom, the following are some general considerations to keep in mind:

1. Ask visually impaired students if they need help on specific tasks, but do not assume they do. If help is needed, the students will say so.
2. The use of contrasting colors, such as light versus dark, can help students differentiate between cables and routers.
3. Proper lighting in all areas of the lab is important for all students to see more effectively.
4. For students with low vision, pocket or lighted magnifiers can assist with reading.
5. For students with low vision, a hat or visor may help cut the glare that is associated with many vision disorders.
6. In teaching or presenting information, use bold lines and write in large print.
7. In the classroom, it is important to encourage all students, but especially visually impaired students. If hopelessness or fear sets in, a social worker or special teacher of the visually impaired may be called in to help these students cope with their learning environment.

When there are hearing-impaired students in a classroom, the following are some general considerations to keep in mind:

1. Make sure the labs are well lighted so the speaker can be clearly seen.
2. Be sensitive to background noise in the lab. Turn off all radios, cell phones, and televisions during work times. If background noise is unavoidable with online learning, have hearing students use ear phones to keep noise to a minimum.
3. Speakers should get close to the student.
4. Stress the importance of only one person talking at a time during group work.
5. Initiate conversations with students by specifically calling their names, and setting the purpose of the conversation.
6. Be patient when students may be tired or frustrated with the impact of their disabilities in the lab-learning environment.
7. Speak face to face. It is important to be on equal eye level with a student when having a conversation.
8. For students who are speech-readers, sentences or phrases may need to be reworded to convey a message. Also, be conscious of speaking distinctly and not too fast.

When there are physically disabled students in a classroom, the following are some general considerations to keep in mind:

1. Be prepared to give physically challenged students more time if necessary to complete tasks and exams during hands-on lab work.
2. Think about giving these students shorter work assignments with rest periods built into the schedule.
3. Establish open communication with the student, parent, and/or doctor to find the right balance of work that matches individual endurance and capability.
4. Rethink configuration of lab space to accommodate wheel chairs and other transportation aids.
5. Provide preferential seating in the lab to accommodate transportation devices.
6. Offer a copy of instructor notes to the student for review on tests.
7. Use a computer for testing.
8. Students with physical disabilities may require devices such as word processor, ergonomically designed furniture, laptop computer, a Kurzweil print reader, portable tape recorder for books on tape, and voice synthesis program, to name a few.

Web Links

Disabilities, Teaching Strategies, and Resources

<http://www.as.wvu.edu/~scidis/sitemap.html>

B.1.9 Learning disabilities

What are some words commonly associated with learning disabilities?

- **Dyslexia**, perhaps the most commonly known, is primarily used to describe difficulty with language processing and its impact on reading, writing, and spelling.
- **Dysgraphia** involves difficulty with writing. Problems might be seen in the actual motor patterns used in writing. Also characteristic are difficulties with spelling and the formulation of written composition.
- **Dyscalculia** involves difficulty with math skills and impacts math computation. Memory of math facts, concepts of time, money, and musical concepts can also be impacted.
- **Dyspraxia (Apraxia)** is a difficulty with motor planning, and impacts upon a person's ability to coordinate appropriate body movements.
- **Auditory Discrimination** is a key component of efficient language use, and is necessary to "break the code" for reading. It involves being able to perceive the differences between speech sounds, and to sequence these sounds into meaningful words.
- **Visual Perception** is critical to the reading and writing processes as it addresses the ability to notice important details and assign meaning to what is seen.
- **Attention Deficit (Hyperactivity) Disorder (ADD/ADHD)** may co-occur with learning disabilities (incidence estimates vary). Features can include: marked over-activity, distractibility, and/or impulsivity which in turn can interfere with an individual's availability to benefit from instruction.

Figure 1: Learning Disabilities

The odds are overwhelming that instructors will have at least a few students with learning disabilities in most of their classes. The following list summarizes some approaches to teaching students with learning disabilities. It should be noted that many of these suggestions apply equally well to students without learning disabilities.

1. Gain student attention with lesson starters that illicit emotion and feelings. This introduction to learning tells the brain it is time to pay attention.
2. Provide opportunities for teamwork. Often students with learning disabilities will respond to peer interactions with a higher level of motivation to achieve than when working alone.
3. Teach students to write their own personal learning goals. Write short and long-term goals and provide feedback on progress.
4. Provide numerous models, examples, and representations of curriculum concepts.
5. Many learning disabled students benefit when teachers speak aloud in class. The instructor works through a problem or addresses a challenge by talking out loud about the steps and thinking that occurs during the process.
6. For many learning disabilities, the use of simple memory tools can help the students process information for retrieval at a later time. These gimmicks are called mnemonics and may come in the form of a catchy rhythm or unique pattern of language that is easy to remember. Examples are the use of pictures, music, color, and even movement. This strategy strongly mirrors Howard Gardner's work with multiple intelligences.
7. Use visual advance organizers to introduce new concepts as well as analyze and synthesize final understandings. Through organizers, the brain gets a clear message that new content is coming. This technique facilitates new knowledge building upon existing knowledge.
8. Humor is a powerful stimulant to the brain. It easily latches onto the silly and unimaginable.
9. For learning disability (LD) students, movement and action are important motivators and can help some students process information. The hands-on lab times will greatly benefit LD students.
10. Reflection retains new understanding into long-term memory. At different points during the day, have students talk about or write about what they have learned, what they found interesting, and what they still need to learn.
11. Time takes on a new importance to learning disabled students. Be ready to offer additional time for LD students to formulate responses to questions.
12. It is important for LD students to learn while they are in an emotional state that is free from anger and extreme frustration. Students have an easier time getting through tasks when they are calm and focused.

Web Links

National Center for Learning Disabilities

<http://www.ncld.org/>

Strategies for Teaching Students with Learning Disabilities:

<http://www.as.wvu.edu/~scidis/learning.html>

B.2 Lab-centric Instruction

B.2.1 CCNA labs

The CCNA curriculum prepares students to plan, design, install, operate, and troubleshoot TCP/IP, Ethernet, and routed and switched networks with some remote connectivity.

The CCNA curriculum consists of four courses. They are Networking Basics, Routers and Routing Basics, Switching Basics and Intermediate Routing, and WAN Technologies. The curriculum is lab intensive, with approximately 50 percent of all class time spent in lab exercises.

In CCNA 1, required equipment includes workstations, hubs, switches, a variety of cable making and cable testing tools, and cable installation materials. Students acquire lab skills such as configuring networking properties on workstations, making and testing patch cables, and installing and testing cable runs, jacks, and patch panels.

In CCNA 2, required equipment includes workstations, hubs, switches, and routers. Students acquire lab skills such as interconnecting networking devices, router configuration and testing using the Cisco Internetworking Operating System (IOS), and building and troubleshooting a five-router network.

In CCNA 3, required lab equipment includes workstations, hubs, switches, and routers. Students acquire lab skills such as switch configuration, VLAN configuration, intermediate routing protocol implementation, and the use of Access Control Lists to provide traffic control and security on a simple network.

In CCNA 4, required lab equipment includes workstations, hubs, switches, and routers. Optional but highly recommended WAN simulation equipment is also available. Students acquire lab skills in WAN technology areas of Point-to-Point Protocol, ISDN, and Frame Relay. Students also must pass a comprehensive lab (skills) exam as part of this course.

Standard and premium lab bundles are available, along with a wide variety of optional bundles. The student-to-equipment ratio should be kept as low as possible.

Web Links

Cisco Networking Academy Program

<http://cisco.netacad.net/>

B.2.2 CCNP labs

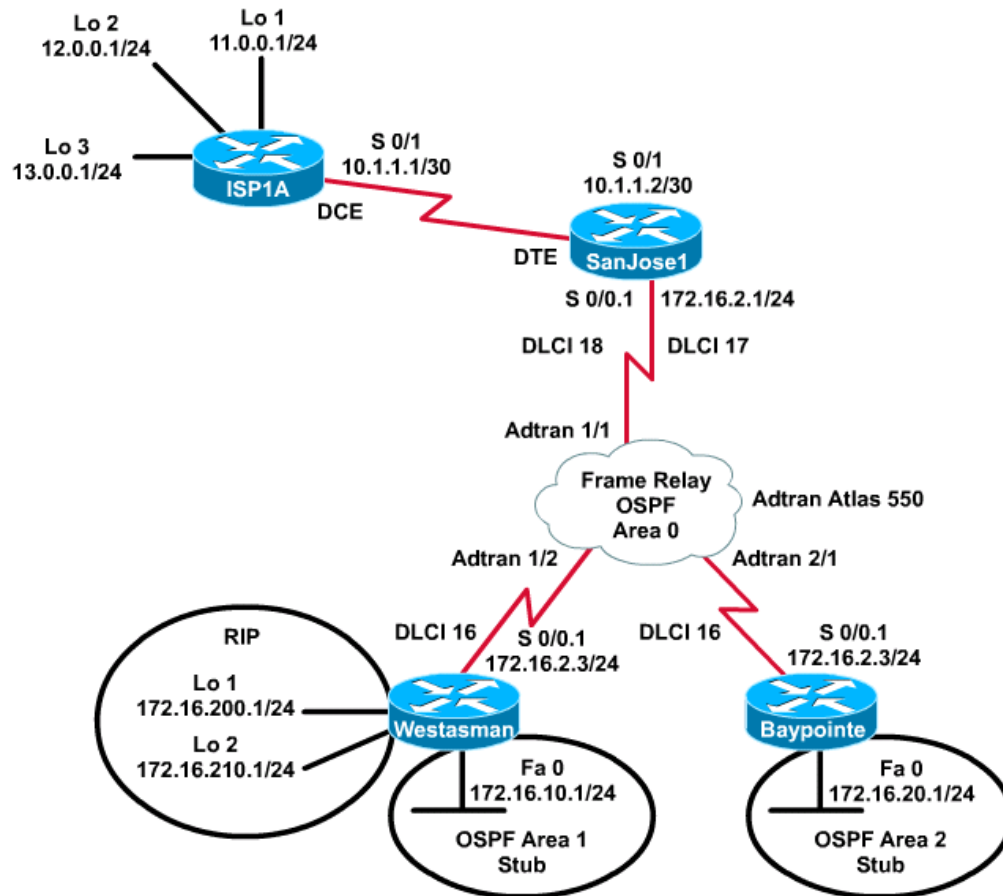


Figure 1: CCNP Labs

The CCNP curriculum prepares students to plan, design, install, operate, and troubleshoot the enterprise-level of TCP/IP, Ethernet, and routed and switched networks with substantial remote access.

The CCNP curriculum consists of four courses. They are Advanced Routing, Remote Access, Multi-layer Switching, and Network Troubleshooting. The curriculum is lab intensive, with approximately 50 percent of all class time spent in lab exercises.

In CCNP 1, required equipment includes workstations, routers, and switches. Students acquire lab skills such as designing scalable networks, implementing advanced IP address management techniques, and configuring and testing the routing protocols, such as EIGRP, OSPF, and BGP. This helps make most enterprise Intranets and the Internet possible.

In CCNP 2, required equipment includes workstations, routers, switches, and a WAN simulator. Students acquire lab skills such as WAN design, configuring and testing dial-up, point-to-point, ISDN, Frame Relay, and X.25 WAN protocols, and basic network security.

In CCNP 3, required lab equipment includes workstations, hubs, switches, and routers. Students acquire lab skills such as switch and VLAN configuration, implementation of multi-layer switching and redundancy technologies, and campus LAN design.

In CCNP 4, required equipment includes workstations, routers, switches, and a WAN simulator. Students acquire lab skills in troubleshooting LANs, WANs, switches, routers, TCP/IP protocols, and routing protocols.

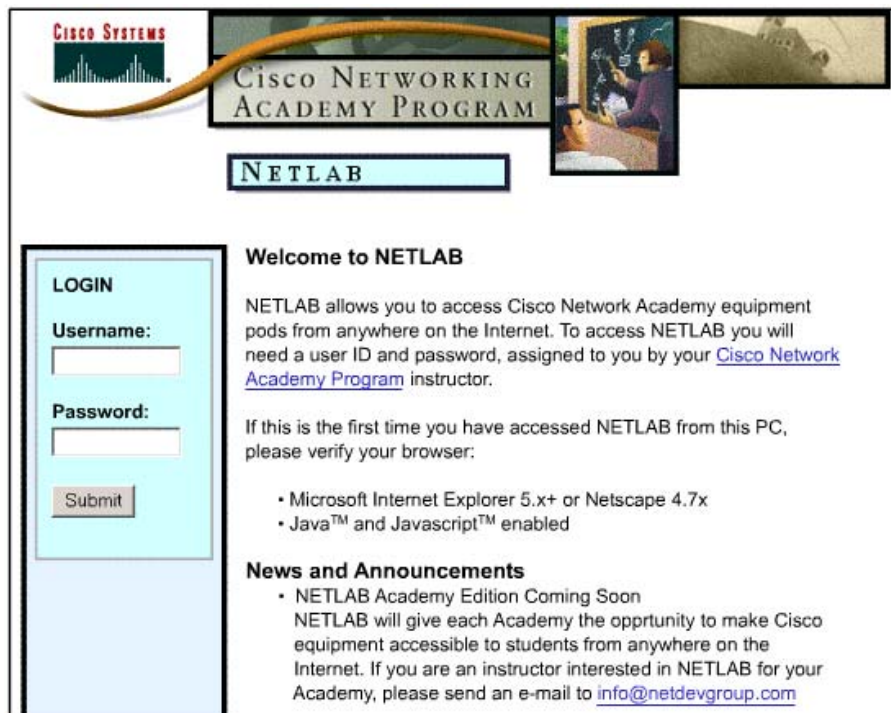
Standard and premium lab bundles are available, along with a wide variety of optional bundles. The student-to-equipment ratio should be kept as low as possible.

Web Links

Cisco Networking Academy Program

<http://cisco.nteacad.net>

B.2.3 NETLAB



The screenshot shows the NETLAB login interface. At the top, there is a Cisco Systems logo and the text 'Cisco NETWORKING ACADEMY PROGRAM' and 'NETLAB'. Below this, there is a 'LOGIN' section with fields for 'Username:' and 'Password:', and a 'Submit' button. To the right of the login section, there is a 'Welcome to NETLAB' message, followed by a paragraph explaining that NETLAB allows access to Cisco Network Academy equipment pods from anywhere on the Internet. It also mentions that users need a user ID and password assigned by their Cisco Network Academy Program instructor. Below this, there is a note about verifying the browser if it's the first time accessing NETLAB from this PC, with a list of requirements: Microsoft Internet Explorer 5.x+ or Netscape 4.7x, and Java™ and Javascript™ enabled. At the bottom, there is a 'News and Announcements' section with a bullet point stating 'NETLAB Academy Edition Coming Soon' and providing information about how to make Cisco equipment accessible to students from anywhere on the Internet, including an email address: info@netdevgroup.com.

Figure 1: NETLAB

To boost student access to hands-on experiences, many educators are interested in remote access to shared lab equipment. Technologies exist that allow many courses, including the CCNA, CCNP, and sponsored curriculum, to apply remote access technologies. This helps lower the student-to-equipment ratios in a variety of distance learning situations. Currently, these technologies have been fully implemented only for the CCNA courses. This course will examine this issue in more depth and suggest how instructors and Academies can use these particular technologies or implement their own version of them.

Cisco Networking Academy is now offering the NDG NETLAB solution. This web-based appliance will allow Cisco Networking Academies to host live router topologies and curriculum over the Internet. Using the automation and sharing capability of NETLAB, Cisco Networking Academies can maximize the use of their equipment, saving money in the process. The networking hardware is identical to the lab bundle used in Cisco Networking Academies worldwide.

This will allow students to maintain a consistency of topology in order to practice configuration commands covered in the Academy curriculum and labs. Depending on how the instructor has decided to use NETLAB in the Cisco Networking Academy, students will be allowed to log in, create and edit configuration files, and program one or more of the devices. Students may also work in teams to configure an entire topology or schedule individual time to practice new commands. Since the NETLAB environment includes equipment similar to that used by Cisco Networking Academy Program, students can practice configuration tasks just as they would with their Networking Academy equipment. However, because the NETLAB equipment can be accessed from any PC with a browser connected to the Internet, students can perform these configuration tasks from virtually anywhere. This usually means that students will be accessing the equipment in the evening or on the weekends from home or some other online location. However, some instructors may choose to implement use of the NETLAB system within the classroom. This is especially useful when students are just beginning to learn new configuration tasks. The instructor can lead the class through a lab by using the instructor-led lab features of NETLAB. During instructor-led sessions, the instructor can issue configuration commands to one or more devices while students follow the telnet session. Another way instructors use NETLAB within the classroom is the team approach. A team of students is given the assignment of configuring one or more of the routers in the topology. The team can share access and control over the router using NETLAB, while other teams work to configure other routers in the topology. Since NETLAB can save and store these configuration files, it is easy for the instructor to evaluate performance of each team.

Instructors review work students have performed on real equipment by using NETLAB. During each lab reservation, NETLAB records every command and router output in log files. Final equipment configurations made by the students can be saved for instructor review. This feature allows instructors to determine what ability the student has to implement the concepts learned in the classroom. Instructors are also able to identify and correct common mistakes made by students during lab exercises.

NETLAB is currently deployed as a pilot program at selected Cisco Networking Academies. Upon successful completion of this pilot program, Cisco will be offering NETLAB to all Cisco Networking Academies. For information on how to become one of the Academies participating in the NETLAB project pilot, please e-mail netlab-pilot@cisco.com with an expression of interest. Cisco will send a survey that will help identify any changes that will need to be made in order for the NETLAB tool to function, plus information on how to order the necessary equipment. Please e-mail netlab-question@cisco.com any questions or requests for additional information. This is designed to minimize potential deployment problems and to enhance the success of a production deployment. Academies will be selected for this program based upon a review of several factors. Technical capacity will be one of the more important criteria. A survey will be provided to interested Academies to identify the requirements needed in order for this solution to be successful. To implement this solution, Academies will need to have the proper infrastructure in place as well as be able to demonstrate a sufficiently high level of technical expertise.

To learn how to utilize NETLAB, the Cisco Networking Academy Program has created Comprehensive Administrator, Instructor and Student guides, as well as an online curriculum. Although NETLAB will seem intuitive and easy to use, administrators and instructors should spend time becoming familiar with the numerous features of NETLAB.

Web Links

NGD NETLAB

<http://www.netdevgroup.com/netlab.htm>

B.2.4 Simulations

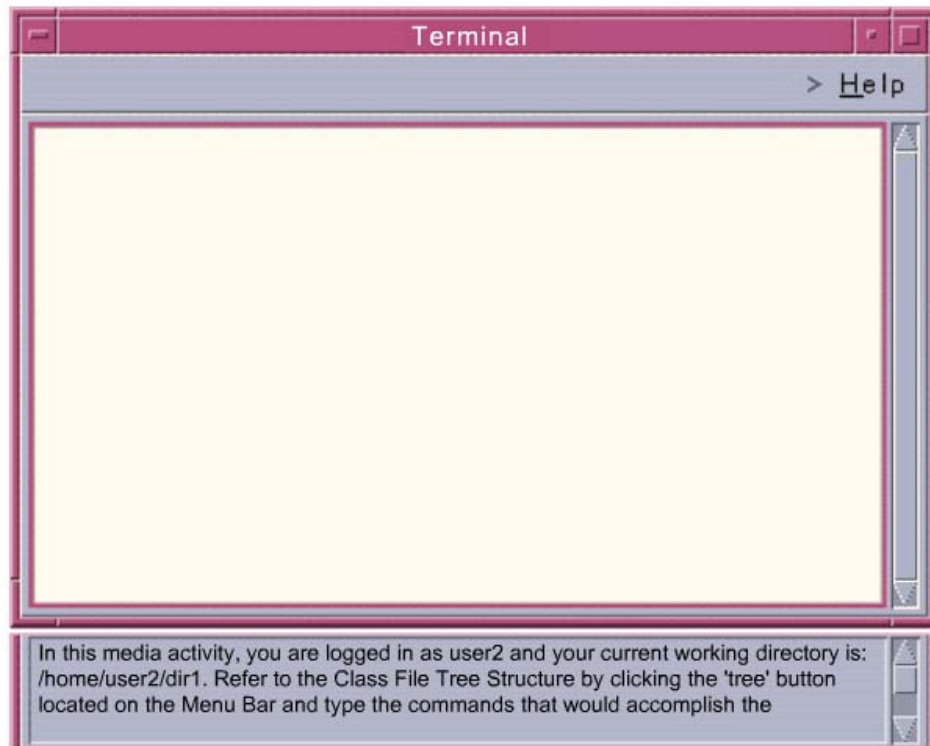


Figure 1: Simulations

Research indicates that learning is more extensive when the content is interactive and capable of providing instant feedback. Academy curriculum contains a wide variety of interactive Flash activities. One class of these activities is "simulation". Examples of "simulation" are focused on such content as command-line interfaces, Graphical User Interfaces, and Programming Language development environments.

The graphic associated with the content of this section, shows an example simulation activity from the UNIX curriculum. The Help feature can be used in the simulation to obtain the necessary information to complete the required task.

In general, there are three levels of academy simulations. The simplest, most scripted, activity can be thought of as a syntax drill. This exercise is meant to give students immediate practice when a new command or procedure is introduced. These simulations help move online curriculum away from an "e-reading" approach to a more interactive "e-learning approach".

The second level, which can be thought of as a lab drill, involves simulating hands-on labs and programming tasks step-by-step. The hands-on lab or programming/configuration task has a complete flash analogue that can be done by students even if they have no access to the lab equipment.

The third level, called simulations, is the most open-ended environment. Rather than being scripted, a wide variety of actual hardware and software behavior is supported. For command line interfaces, such as IOS or UNIX, many commands can be issued in any order. The best current example of this third level simulation environment is e-SIM, which is available and free to all CCNA and CCNP students.

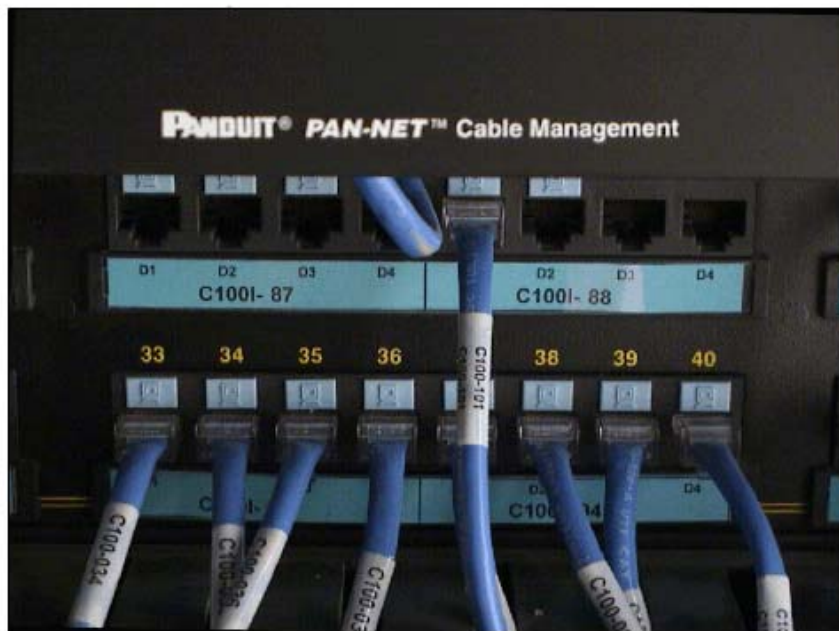
Flash simulations are not meant to substitute for, but rather complement hands-on experience with lab equipment and actual programming. They have many cognitive benefits. For example, simulations allow students to perform a simulative pre-lab activity prior to an actual lab activity. This helps a student increase their comprehension in a simulated environment before being required to demonstrate a final proficiency with actual hands on equipment and programming. In the future, many more simulations across the curricula will be developed for the Academy Program.

B.2.5 Sponsored curriculum labs



IT Essentials I and II: Sponsored by Hewlett-Packard

Figure 1: Sponsored Curriculum Labs



Fundamentals of Voice and Data Cabling: Sponsored by Panduit

Figure 2: Sponsored Curriculum Labs



Fundamentals of UNIX: Sponsored by Sun Microsystems

Figure 3: Sponsored Curriculum Labs

The six sponsored curricula also require dedicated labs and a variety of hardware and software. They are summarized as follows:

IT Essentials: PC Hardware and Software IT Essentials 1

PC Hardware and Software, sponsored by Hewlett-Packard Company, presents an in-depth exposure to computer hardware and operating systems. Students learn the functionality of hardware and software components as well as suggested Best Practices in maintenance, and safety issues. Through hands-on activities and labs, students learn how to assemble and configure a computer, install operating systems and software, and troubleshoot hardware and software problems. In addition, an introduction to networking is included. This course helps students prepare for the CompTIA A+ certification exam. Although this is designed as a 70-hour course, it addresses a broad range of topics that might benefit from a longer delivery model.

IT Essentials: Network Operating Systems 1

Network Operating Systems, sponsored by Hewlett-Packard Company, is an intensive introduction to multi-user, multi-tasking network operating systems. Characteristics of the Linux, Windows 2000, NT, and XP network operating systems will be discussed. Students will explore a variety of topics including installation procedures, security issues, back up procedures and remote access. This is a 70-hour course, which includes hands-on labs that utilize the Windows 2000 and Linux network operating systems.

Fundamentals of Voice and Data Cabling 2

The Fundamentals of Voice and Data Cabling Course, which is sponsored by Panduit, is designed for students interested in the physical aspects of voice and data network cabling and installation. The course focuses on cabling issues related to data and voice connections and provides an understanding of the industry and its worldwide standards, types of media and cabling, physical and logical networks, as well as signal transmission. Students will develop skills in the following areas:

- Reading network design documentation
- Parts list set up and purchase
- Pulling and mounting cable
- Cable management
- Choosing wiring closets
- Patch panel installation
- Termination
- Installing jacks and cable testing

This is a hands-on, lab-oriented, 70-hour course. It stresses the following competencies:

- Documentation
- Design
- Installation issues
- Laboratory safety
- On-the-job safety
- Working effectively in group environments

Fundamentals of UNIX 3

Fundamentals of UNIX sponsored by Sun Microsystems teaches students the following concepts:

- Use UNIX operating system commands
- Hands-on experience with basic Sun Microsystems Solaris operating environment commands
- Introduces the Common Desktop Environment (CDE) a graphical interface between different environments

This class is intended for new users of UNIX. Students will learn the following fundamental command-line features of the Solaris environment:

- File system navigation
- File permissions
- The vi text editor
- Command shells
- Basic network use

CDE features include Standard Desktop Tools, Text Editor, printing, and mail. The course is designed for 70 hours. About half of this time is spent using the instructor-facilitated online multimedia material and the rest is spent on lab exercises.

Fundamentals of Java Programming

Fundamentals of Java programming, sponsored by Sun Microsystems, provides a conceptual understanding of object oriented programming. The course also teaches students how to use the JAVA language object oriented technologies to solve business problems. Topics include the language fundamentals and the Java language application programming interface (API). Students will learn how to create classes, objects, and applications using this language. Additionally, the course addresses the demand for training and preparation to be a Sun Certified Programmer for Java 2 Platform. Although designed as a 70-hour course, it addresses some very advanced topics that might benefit from either a longer delivery model or some pre-selection, and screening of students.

Fundamentals of Web Design

Fundamentals of Web Design, sponsored by Adobe Systems, will focus on the overall production processes surrounding website design with particular emphasis on design elements involving layout, navigation, and interactivity. Cisco Networking Academy students will learn Web Design in preparation for higher education or jobs in the Internet economy. Hands-on Web Design exercises will be taught using Adobe® Photoshop®, Adobe Illustrator®, Adobe GoLive, Adobe LiveMotion, and Adobe Premiere®. This course has been designed as a 70-hour course. However, since it uses five Adobe applications, it may be beneficial for either a longer delivery model or some pre-selection, or screening, of students. About half of the course time is spent using the instructor-facilitated online multimedia material and the rest is spent on lab exercises.

Web Links

Instructor Community: New Courses:

<http://cisco.netacad.net/public/academy/catalog/index.html>

B.2.6 Emerging technologies



Figure 1: PIX Security Appliance PhotoZoom



Figure 2: IP Phone

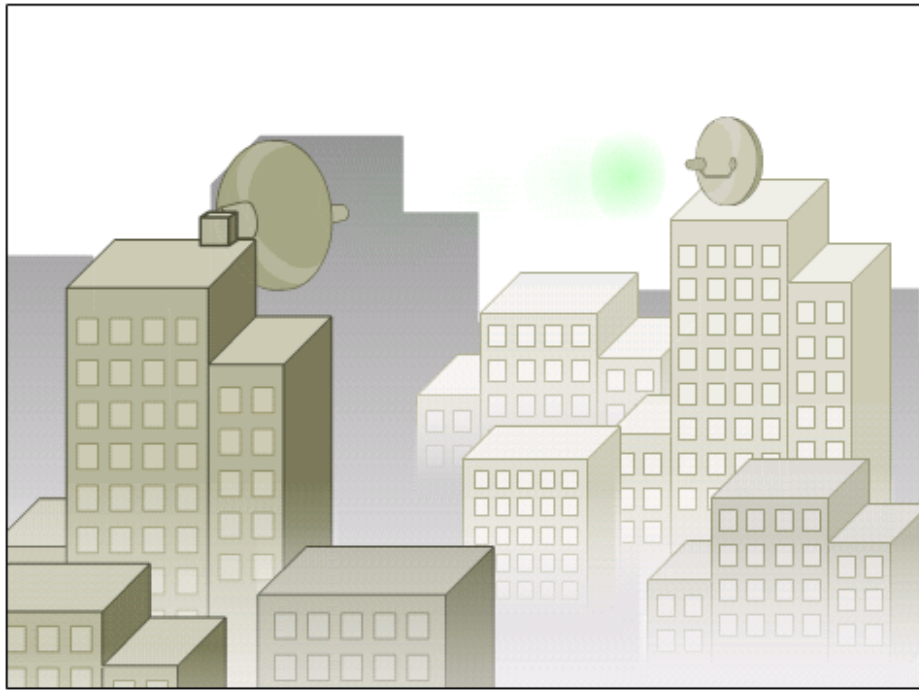


Figure 3: Wireless LAN

In the future, new technologies may be the basis for Academy curriculum. Examples of technologies include Network Security, IP Telephony, and Wireless LANs.

Each of these courses has an associated lab bundle. The expectation is the successful implementation of labs using this bundle equipment. The goal will be to train professionals who can immediately implement Network Security [1], IP Telephony [2], Wireless LAN [3], and other networking technologies.

Web Links

Network security issues:

http://www.cisco.com/warp/public/779/largeent/issues/security/net_security.html

IP Telephony:

<http://www.cisco.com/warp/public/779/largeent/learn/technologies/IPtelephony.html>

Wireless solutions:

<http://www.cisco.com/warp/public/779/smbiz/netsolutions/find/wireless.shtml>

B.2.7 Troubleshooting

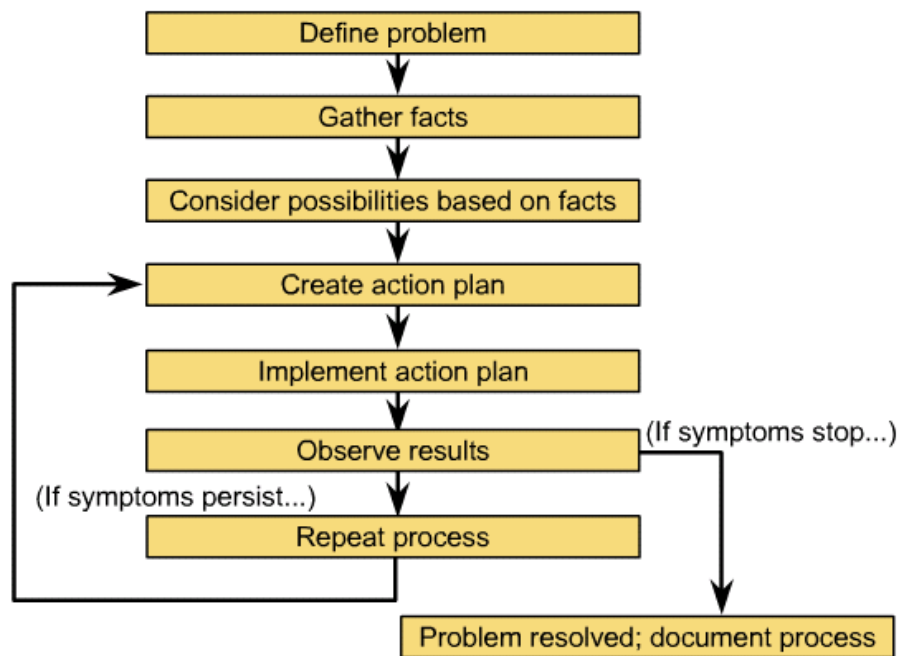


Figure 1: Steps in the Problem-Solving Model

Troubleshooting is a form of educational inquiry particularly relevant to the Cisco Academy curriculum. In most Academy courses, troubleshooting will occur and be necessary even if it is not formally taught.

There are literally over a hundred approaches to troubleshooting. Figure 1 shows one approach. This happens to be the method preferred for teaching Cisco courses. Instructors may use their own preferred method.

Troubleshooting and debugging skills are an absolute necessity for students who seek further education and employment in the IT industry. It is perhaps the most empowering skill that instructors can pass on to their students. Teaching troubleshooting typically requires instructors to spend more time on lab preparation. However, the overall benefit to the student is well worth this investment. The term troubleshooting is used to apply to hardware, software, and programming problems.

One instructional troubleshooting method involves deliberately introducing a finite number of problems in a structured lab environment that have been experienced previously by the students.

With practice, students will be able to diagnose and fix the problems in a finite amount of time. Of course, this method must be integrated with labs that do the following:

- Expose students to a working system
- Demonstrate the typical failure modes of that system
- Allow students to experience first hand the symptoms of those failure modes
- Provide opportunities for students to practice diagnosis and repair

Web Links

Teaching Methods Web Resources:

<http://www.mhhe.com/socscience/education/methods/resources.html>

The Universal Troubleshooting Process (UTP):

<http://www.troubleshooters.com/tuni.htm>

Journal of Technology Education:

<http://scholar.lib.vt.edu/ejournals/JTE/v2n2/html/deluca.html>

B.3 Project-based Instruction

B.3.1 Challenges and projects

NetDay Hero Awards

Each year, NetDay recognizes outstanding individuals who, through their heroic and selfless leadership, have made significant contributions to education and education technology. This award, the NetDay Hero Award, honors individuals who have made a life-long commitment to improving and enhancing educational opportunities for children through the use of technology. 2002 Hero Award Recipients: Elaine and John Chambers



We are proud to honor Elaine and John Chambers as the 2002 NetDay Heroes in recognition of their extraordinary leadership and vision in both their professional and family commitments to education and education technology. The Chambers' have a long-standing history of supporting education as individual philanthropists and corporate citizens. As CEO of Cisco Systems, Inc., John has positioned Cisco's educational programs to represent powerful partnership models for corporations, schools, and nonprofits to achieve results in education.

Elaine and John Chambers received their 2002 Hero Awards at NetDay's annual Family Celebration on March 9, 2002 at The TECH Museum of Innovation in San Jose, CA.

Source: <http://www.netday.org/>

Figure 1: Challenges and Projects

Challenges are problem-based labs or projects, advocated by AAAS Project 2061, a science education reform project. These exercises are the opposite of cookbook, or step-by-step, labs. Instead, they encourage students to work on their own to develop solutions to various problems or challenges. The challenges vary in content and duration, from fifty minutes to three weeks, and are comprised of two basic parts. First, the lab asks students to solve a given problem. Second, it asks the students to create a product. For example, a simple 50-minute challenge lab for the first semester might be titled "Make a Patch Cable That Works Successfully". A three-week challenge that could teach more complex tasks might be called "Wire the School Computer Lab". Net Day is a great example of challenge-based learning and Cisco encourages instructors to incorporate it into their classes.

Teaching and learning environments extend beyond the lab setting. For many Academies, real world opportunities surface when students can use their networking skills in a project that contributes to the productivity of community initiatives. Sometimes these activities are called "service learning".

The origin of the Cisco Network Academy Program is as a community project. In the mid-1990s, educational institutions around the world began to have demand for computer networks that far exceeded the skilled personnel for installing and maintaining those networks. Cisco Engineer George Ward worked to address these issues. Mr. Ward articulated the need for a course sequence that would train high school students to support the networks of their own schools. This need for versatile apprentices became the Cisco Certified Network Associate curriculum.

"Net Day" is where a community volunteers time to "wire" a school. It is a popular focal point form of community projects that involve students, parents, network administrators, and others to get students connected to the Internet. Academy students participate in numerous Net Days.

Another example of a community project comes from the work of the Cisco Academy of South West Ohio (CASWO). This Academy and its students provided technical support for the annual Ohio SchoolNet Technology Conference. Academy students helped set up the network for the conference and provided technical assistance to conference managers and presenters. One quote from a student speaks to the value of this learning experience. "This really helped me see the big picture of how everything works together, and what tech support is like."

Another example of community outreach takes place in Washington, D.C. Here Cisco Systems partners with Mary's Center for Maternal and Child Care. With help from a volunteer system engineer and three students from the Cisco Networking Academy Program at Bell Multicultural High School, Mary's Center now has a fully operational wireless network that can support their computer needs. Now the center can access important health and insurance information needed to assist families and their children. To Academy students, the benefit of working on real world project is amazing. Says Max Anis, Networking Academy instructor at Bell High School, "These students return to the classroom with an incredible amount of energy after these experiences. As a result, they are even more determined to complete the program and continue their pursuit of a career in the industry."

B.3.2 Design activities

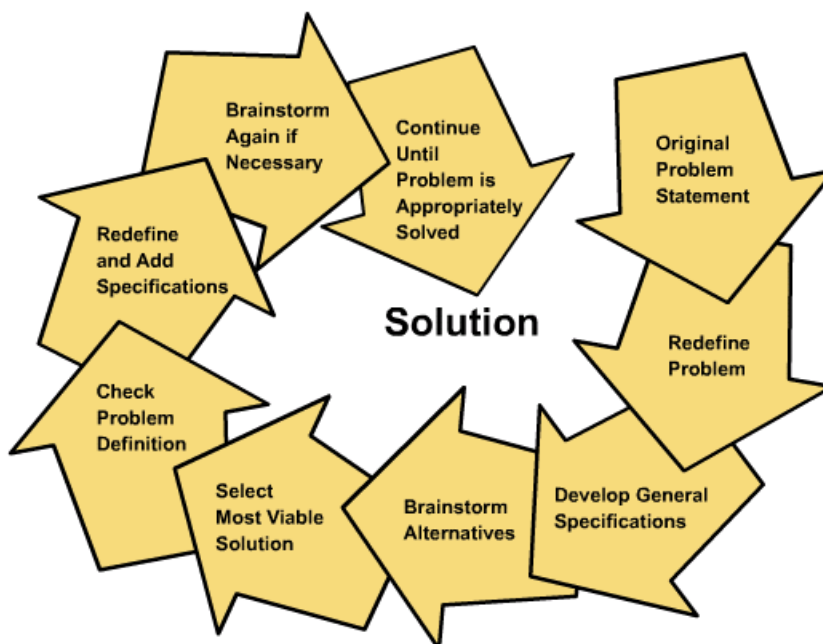


Figure 1: Dartmouth Problem-Solving Cycle

Design is an iterative process that starts with brainstorming. From there, it proceeds through research and problem-solving matrices and design specification tests. Finally, it requires multiple repetitions of this process until an adequate solution to a problem is achieved. In any Academy, curriculum that has a project or design activity might consider introducing elements of the Dartmouth Problem-Solving and Design Method. The website associated with this section has online resources as well as written materials that may be downloaded. There is also a video that may be ordered. Of course, there are other methods that work well. Cisco encourages instructors to use the method that works best for them and their students.

Students could troubleshoot problems in an existing network, or design and check a network in order for it to meet specifications. Either way, the process involves an iterative problem-solving procedure. For internet-working problems, and issues around general engineering, problem-solving matrices are always useful whenever there are a number of alternatives for a given number of constraints. Chapter 1, "The Engineering Problem-Solving Cycle of the Engineering Problem-Solving for Mathematics, Science, and Technology Education" uses the problem-solving matrix to introduce the problem-solving cycle and its iterative nature. Most importantly, use of the matrix exposes students to the intricate skill of defining a problem. Chapter 4, "Guiding Students Through the Problem-Solving Cycle", gives suggestions on iterating the entire process. This includes more detail on how to choose effective problems, how to set up the right environment for brainstorming sessions, and how to analyze the results of these sessions.

The hope is that students will gain an appreciation for the importance of problem-solving, which is one of the most important aspects of engineering. In addition, Cisco wants students to experience the process of using these procedures to gain a better understanding of why some potential solutions work and why some do not. They will learn that employing good problem-solving procedures and documentation will ultimately determine their success in finding solutions to problems. As time goes by, they will be able to use the lessons learned from past failed problem-solving attempts to save valuable time when trying to solve new problems.

Chapter 5, "Research, Documentation, and Testing" is a good resource for conducting site surveys, keeping work logs, producing engineering reports, and creating portfolios.

Web Links

Dartmouth Problem-Solving and Design Method

<http://thayer.dartmouth.edu/teps/index.html>

B.3.3 Brainstorming

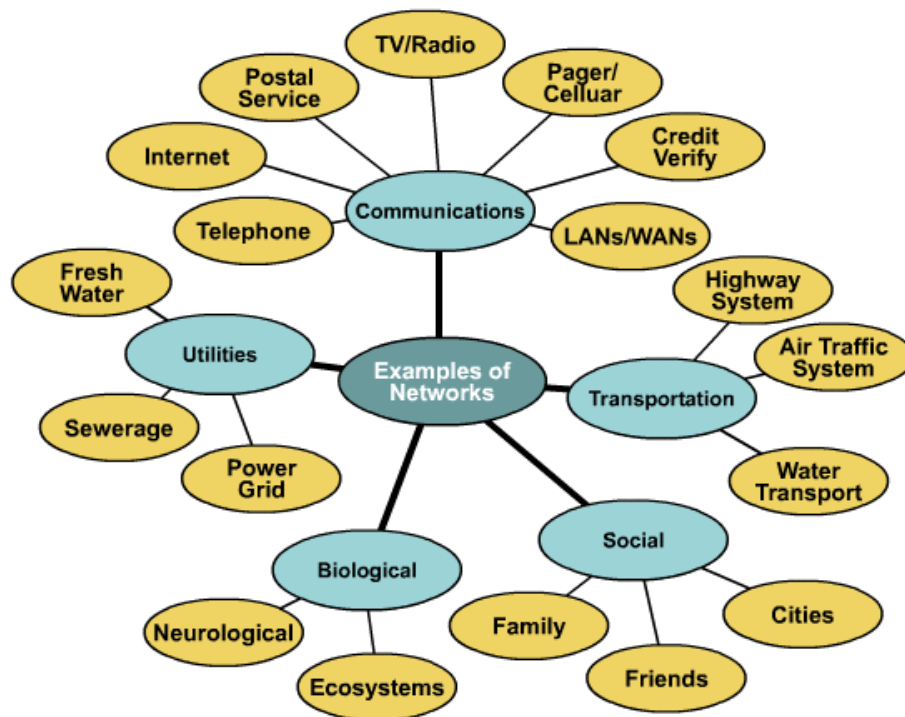


Figure 1: Cluster Diagram

Brainstorming techniques can be useful for teaching IT curriculum. This can range from simple introductions to new topics to more integral parts of design work. Responses to the prompt, "What does the word 'network' mean?" are shown in this graphic. The following are simple rules established for this brainstorming activity:

- The wildest possible ideas are accepted.
- There will be no censorship of ideas.
- They are looking for quantity.
- Build on the ideas of other people.

Another method for brainstorming is called Carousel Brainstorming. This is a strategy used for creative thinking when multiple solutions are possible to solve an issue or problem. During a carousel session, problems are documented on large sheets of chart paper around a room. Students in small cooperative groups are given different colored pens and asked to go around the room and brainstorm solutions to the problems listed on the different chart papers. This is done in 30-second rotation sessions. The process continues until students have an opportunity to respond to all problems or issues listed on papers around the room.

SCAMPER is another example of brainstorming that gets students to think creatively. It was first implemented in the 1940s by Alex Osborne and later revised in the early 1980s by Bob Eberle. SCAMPER presents a series of questions to be presented around a new process or knowledge. After encountering new information, students respond to the following questions:

Substitution – What material, methods, processes, times, and so on, can be used in place of this?

Combine – What materials, methods, processes, and times might be combined or added to influence this issue or problem?

Adapt – Can the materials, methods, processes, and times be used in another way to find a solution?

Modify – Can this be made bigger and stronger and more frequent? Can this be made smaller and more compact?

Put to other use – Can this be used instead of other materials, methods, processes, times, and so on?

Eliminate – Can this part be done without?

Reverse – Can the work be done backwards? Can this process be reversed?

Above all else, SCAMPER allows students to think creatively. It emphasizes that no response is too inconceivable.

Web Links

Gifted Education - A Resource Guide for Teachers:

<http://www.bced.gov.bc.ca/specialed/gifted/process.htm>

Scamper

<http://www.discover.tased.edu.au/english/scamper.htm>

B.3.4 Case studies

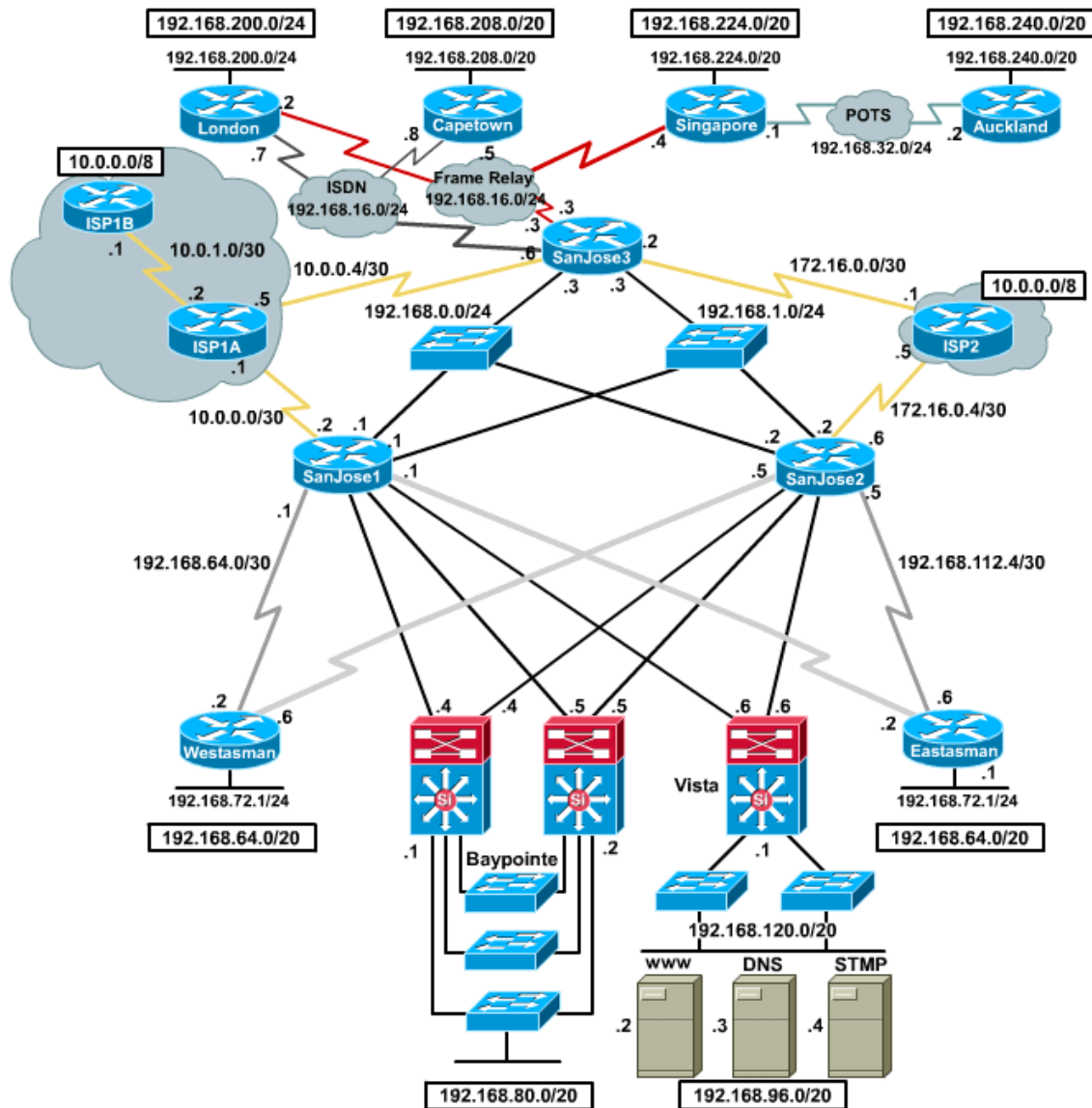


Figure 1: Case Studies

Case study teaching methods have grown in importance in many professions including law, medicine, and business. Throughout the various Academy curricula, case studies, either the ones specified in the course or instructor-developed, can integrate many concepts.

The figure shows one case study from the CCNP curriculum. The International Travel Agency is a fictitious business for which a CCNP might be asked to provide network services.

Web Links

Use of Master Classroom Technology to Implement a Case Study Approach to Learning:

<http://www.mtsu.edu/~itconf/papers96/MASTER.HTM>

Case Study Teaching in Science: A Bibliography:

<http://ublib.buffalo.edu/libraries/projects/cases/article2.htm>

B.3.5 Web research

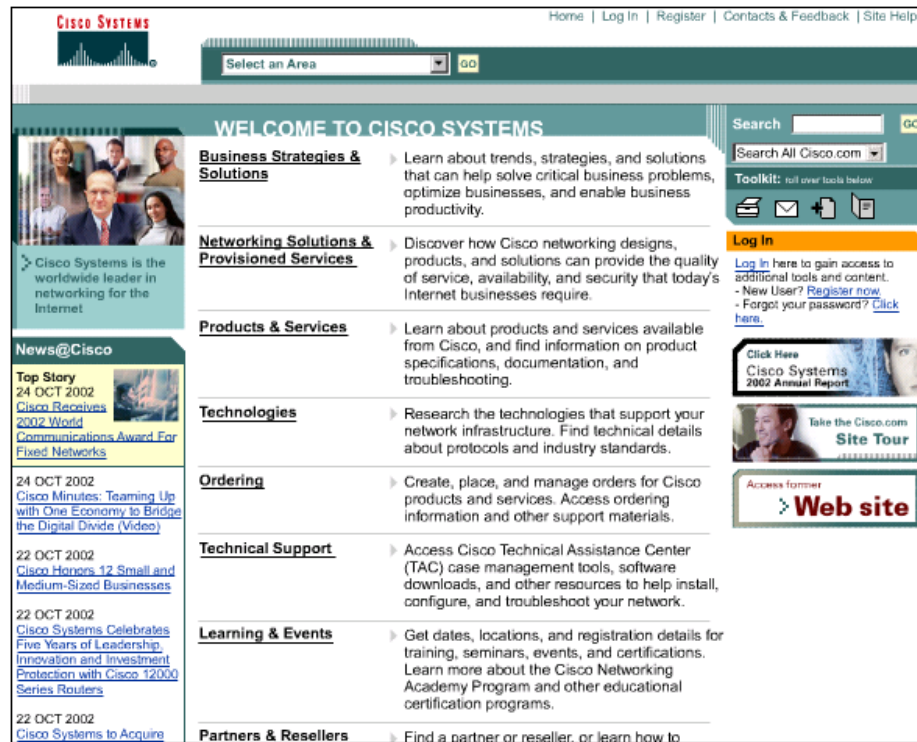


Figure 1: CISCO.com

The Internet has a tremendous amount of resources for those who want to understand or install networks. Students will also be able to research specific products, questions, or extension activities. Cisco encourages students to use the wide variety of links built into the Instructors Guide, or to use their favorite websites. The online documentation at Cisco, Sun, HP, Panduit, and other sponsors will become particularly important. In terms of bandwidth capabilities, the web resources for teaching networking far exceed any textbook or online curriculum. Of course, students must find the resources and as always, be a cautious consumer. Using the Internet as a resource is also a very useful skill for students to develop.

Web Links

Cisco

<http://www.cisco.com/>

Sun

<http://www.sun.com/index.xml>

Adobe

<http://www.adobe.com/>

Panduit

<http://www.panduit.com/>

Hewlett Packard

<http://www.hp.com/>

Google

<http://www.google.com/>

Yahoo

<http://www.yahoo.com/>

B.4 Instructional Strategies

B.4.1 Instructor-led classrooms

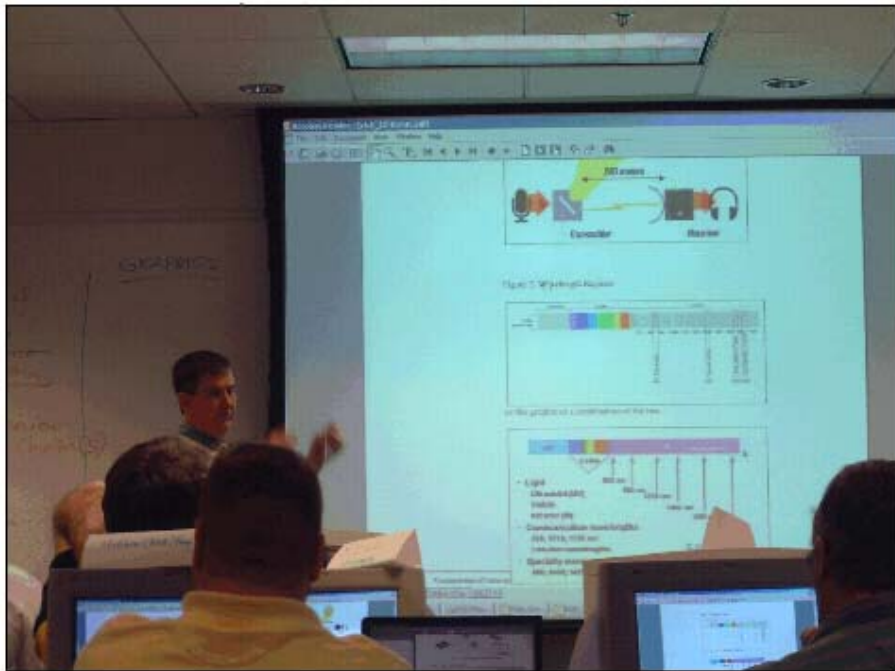


Figure 1: Instructor-Led Classrooms

This style of teaching represents the most common approach to teaching and learning today. Academy courses ask instructors to communicate information to students based on required competencies and performance objectives. Instructor-led environments allow instructors to cover a specified subject matter with a whole group or small group of students at the same time. This style of teaching can take place in an extended time frame, which might take up an entire class period or in a shorter time frame as a mini-lecture. Mini-lectures focus on smaller chunks of content that students may need to hear at any given time during the learning process. An effective classroom strategy for this style of teaching is to have all lectures given at a predetermined class time and as a precursor to individual and group work. With a huge focus today on cooperative dynamics of learning, the importance of dedicating time to knowledge-based process and procedure has been forgotten. Within the instructor-led environment, teachers can review strategies for active listening that will help students become more disciplined listeners which in turn will prepare them to be more effective communicators in the academic and working world.

A mini-lecture is a ten-minute lecture format that might consist of the following elements:

- A hook
- A pre-test or focus question to test for understanding
- The actual lecture
- A short question or activity
- A test for understanding, possibly using just a simple question

Studies have found that relatively short, engaging lectures that include demonstrations are an excellent supplement to the online curriculum and lab activities.

B.4.2 Self paced instruction

Academy courses implement self-paced instructional teaching and learning strategies. Self-paced instruction allows students to learn new content at a pace that best fits their learning style. This content is best presented in modules, which are sessions of learning that fit together into a comprehensive whole. Modules work especially well because students have an opportunity to acquire new understandings in smaller amounts. This method of teaching and learning can be seen in an online environment. Self-paced instruction in an online environment allows students to learn new competencies or knowledge in a flexible time and space. The purpose of online learning should be stated early in the course so students understand what objectives and performances they will be required to master during a course experience. As they begin studying the new content, students will encounter linked resources through the Internet and other electronic connections. Through exploration and experimentation, online learning will ask students to get actively involved with the content. The student will gain interest in the subject through curiosity and inquiry. Self-paced instruction will provide the path to their success. With online or self-paced programs, the instructor has an important part in helping the students get through the course. This role is to help get students excited and keep them excited about what they are learning. Monitoring progress is also a key component of their responsibilities.

While the online lessons are an important part of Academy instruction, they should not be overly used. Remember that a primary goal of the Networking Academy is to train students to design, install, and maintain networks. This is fundamentally a hands-on, problem-based, lab-based endeavor. When the online curriculum is used in the classroom, there should be one to two students viewing content at each computer as the instructor circulates throughout the room checking for problems and comprehension. Periodically, instructors will interrupt students with additional information or clarification on content.

The Study Guide provides an organized method for students to record the important concepts of the lesson. This guide can be used later for review and reflection.

- Learning – Knowledge is gained through vocabulary, content, and activities.
- Vocabulary – List and define new terms using the Glossary.
- Notes/Ideas –Take note of important information from this lesson.
- Activity – Complete the activity assigned in class.
- Applying – Organize, plan, record process, draft, record findings, and show the results of the performance lab or activity.
- Reflecting – Think about and respond to questions about the learning, focusing on the content, product, process, and progress.

B.4.3 Cooperative/collaborative work

Students will be working in various groups for extended periods of time. It is important for cooperative work among the students. Students work together for the benefit of all group members. Research shows that this cooperative learning environment stimulates cognitive activity. This is especially true in the area of higher order thinking, problem-solving, and collaboration. Students working in cooperative group interactions reach objectives and goals with better accuracy than if working as an individual on a task. Cooperative work is a foundation strategy used by teachers who ask students to analyze and synthesize complex information.

It is a strategy that supports other high level thinking processes such as the creation of graphic organizers and using inductive reasoning to solve problems. Students learn to be team players and acquire life skills that will carry them successfully into the working world. Group work refers to using a variety of student groupings to enhance learning and to create a lively classroom atmosphere. Examples of situations in which students might be grouped together, and the number of students in each, are as follows:

- 2 – Studying online curriculum
- 3 – Doing cabling, lab, and programming activities
- 5 – Taking oral exams, working as network or programming teams

There is a variety of ways to engage students through cooperative learning. Instructors can divide the class into student groups for such activities as reviewing, questioning, learning content, and doing performance labs. It is important, however, that to know how and when to use them for the most effective instruction. The following examples illustrate some of the types of groups and the purposes for which they might be used:

Pairs or partners

For this type of grouping, the following are different methods of "partnering" students for work.

- Each student might choose another student with whom they want to work.
- The instructor assigns partners.
- Students work with other students according to the classroom seating arrangement.

The term "pairs" implies two students, but in fact a pair can be part of a team or larger group. Partners can refer to two or three students if there is an odd number of students in class. A pair may partner with another pair so that when one student is absent, the work may continue without major disruption.

Small groups

This type of group usually has three to five students.

- The students can choose their own partners from other classmates.
- The instructors can assign the partners.
- The students can work with other students according to the classroom seating arrangement.

The student roles within the group may be as follows:

- Formal and assigned
- Informal and unassigned

The formal or assigned role may be that of a leader, a speaker, a note taker, a summarizer, a timekeeper, and so on. In informal groups, roles may be unassigned but naturally assumed by members of the group. Some groups, depending on the task or project, do not require the group members to assume any specific roles.

Teams

A team usually has a specified purpose and has three to ten members. The team members may be as follows:

- Appointed
- Selected by other members of the team
- Grouped informally according to classroom seating arrangements
- Alphabetically selected

- According to some other random method

Team members may or may not have assigned roles depending on the performance task. If there are specific roles, they may be based on skill, interest, or necessity. The end product or result of the team effort may contribute to the grade of the team or individual.

Competitive teams

For competitive team activities, the selection of team members is similar to the preceding description. The competitive team has a specific purpose. The purpose is to compete with other teams to determine which team can produce or accomplish the criteria and objectives of a performance task with the most speed or accuracy. The members of each team receive in advance rubrics and criteria for the tasks.

Large groups

A large group can include a variety of the following student configurations:

- Smaller teams
- Groups
- Partners
- Individuals
- Whole class

It is suggested that the parameters and criteria for large group discussion and participation are established prior to the task or activity. This is done so all of the team members understand their roles and responsibilities within the group.

Whole class

This grouping facilitates activities that might include one of the following:

- Teacher-led
- Student-led discussions
- Demonstrations
- Presentations

This type of group is designed to involve all of the students. The parameters for participation and topic focus are clarified in advance so that all participants understand their role and responsibilities within the class.

Web Links

Teaching Strategies: Group Work and Cooperative Learning:

<http://www.crlt.umich.edu/tstrategies/tsgwcl.html>

Enhancing Student Thinking through Collaborative Learning. ERIC Digest:

<http://www.ericfacility.net/ericdigests/ed422586.html>

B.4.4 Jigsaws

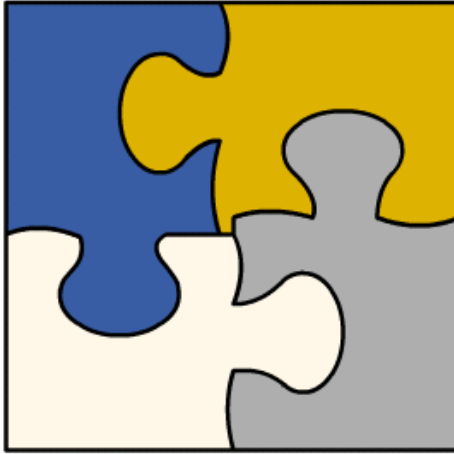


Figure 1: Jigsaw Puzzle

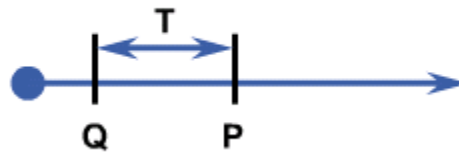
One example of best practice is the utilization of the teaching and learning strategy known as the "expert jigsaw". This concept was first configured by Elliot Aronson in the late 1970s. This particular strategy asks students to take on new information within the dynamics of a group setting. Cooperative group skills are a prerequisite for this type of learning. Students are divided into three groups, which are called home groups. Each group is assigned a number or name. The content to be learned is broken into three sections. The content is dispensed so each student receives one of the three sections of content. Color-coding is a useful technique to implement within this activity. Three different colors distinguish between the three content sections to be learned. Members from each group, by color-coded content, move to an expert group. Here the content is discussed for main points and key understandings. The expert groups undertake this new information with the intent of going back to the larger home group to teach other members the main points of what they learned during the activity. Research states that this is one technique that stimulates significant learning within the brain since it requires critical analysis and articulation before teaching this acquired knowledge to others.

Web Links

Training: How To Do Tasks

<http://www.cvm.tamu.edu/wklemm/logic10.html>

B.4.5 Asking the right questions



Q = Question Asked
P = Prompt Breaks Silence
T = Wait Time

Figure 1: Asking the Right Questions

In classrooms and labs across the country, there are typically two types of questioning skills being implemented, low-level and high-level cognitive questions. Instructors asking low-level questions are looking for responses on basic recall of facts and comprehension based on what has been previously heard in a lecture or read from the curriculum. An example of low-level questioning would be to name the levels of the food pyramid or list the elements found on the periodic table. The most common form of student questioning in school is low-level questioning. High-level questioning is more open-ended and interpretive. Students are required to analyze and synthesize information. With high-level questioning, students are asked to communicate their understanding through logic, reasoning, and evidence. An example of high-level questioning is predicting the next world epidemic or explaining why rockets heading for outer space cannot launch during extremely cold weather.

The average wait time for teachers after asking a question in the classroom is approximately 1.5 seconds. Research states that with just a three second waiting period, answers will be more accurate and organized in thought. It is also known that when asking students questions, to think of the bigger ideas that will create a better understanding that will last long after the little details fade away from short term memory. These big ideas will require teachers and students to continually reflect on the essential worth of the questions that are asked and the truths these questions may uncover. How can improved questioning interactions be achieved in the Cisco Networking Academy Program? This video will examine the question and answer technique used by many instructors in whole-class settings.

The late Dr. Mary Budd Rowe, an accomplished science educator at the University of Florida and Stanford University, studied classroom dynamics. One of Dr. Rowe's great contributions was to study a seemingly "small" topic. The topic was about the time between when an instructor finishes asking the class a question and when the instructor breaks the silence and prompts the class further to respond to the question.

The graphic shows a timeline. At time Q, the instructor finishes asking a question. At time P, the instructor breaks the silence, either with encouragement or the actual answer. Dr. Rowe called the time between Q and P wait time. This small topic nonetheless can lead to significant improvements in student learning.

The instructors in Dr. Rowe's studies averaged about one second of waiting between asking a question and taking further action to elicit a response. Dr. Rowe showed that extending the wait time, for example from about one second to beyond three seconds, produced significant improvements in classroom dynamics.

These included the following:

- Longer responses by students
- More participation by more students with more confidence
- Increases in student-to-student interactions
- More questions asked
- Improvements on complex assessments
- Better classroom management

Consider increasing the wait time when giving a lecture with question and answer techniques to teach networking. See if the additional time helps the student in learning. To learn more, read an excellent article written by Dr. Rowe.

Rowe, M., (1974). Relation of wait time and rewards to the development language, logic, and fate control: a. part one: wait time. Journal of Research in Science Teaching, 11(2), 81-94. b. part two: rewards. 11(4), 291-308.

Also, many resources about different forms of "wait time" are available on the Web by searching Mary Budd Rowe and wait time.

B.4.6 PMI

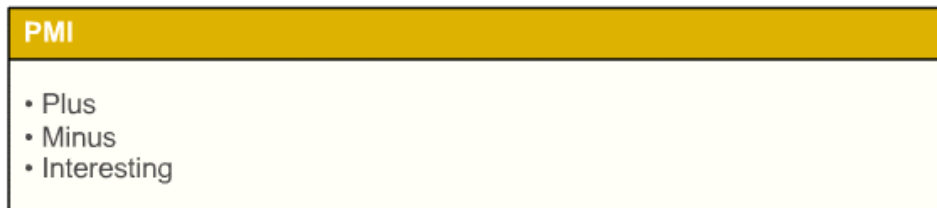


Figure 1: PMI

Many best practice strategies help students think about their thinking or in other words, engage in the process of metacognition. Other strategies encourage students to think creatively where they take a base level of understanding and use this knowledge in new and innovative ways. There are many of these strategies being implemented in classrooms today. However, this section will discuss three methods that are linked to “brain friendly” learning, which creates a blueprint for higher student achievement.

The first method is called Plus, Minus, Interesting (PMI). This practice is metacognitive and asks students to think about their thoughts on new learning. After students have read, heard, or interacted hands on with new information, they create a T-chart. On the left side of the chart is an area for items that might qualify as Plus, Minus, or Interesting. They respond to the following questions in relation to specific content. What do they consider to be a plus? What do they consider to be a minus? What do they consider to be an interesting process, comment or question? Students record their thoughts on the right side of the chart as they apply the categories to the new content. Students can work individually on PMI charts and then share their responses with a partner or a larger group. Ideas and perspectives are shared until common understandings surface. PMI is especially useful during lecture sessions since it provides students the opportunity and method to digest new content.

Web Links

PMI

<http://www.mindtools.com/pmi.html>

Activating and Engaging Habits of Mind:

<http://www.ascd.org>

B.4.7 Graphic organizers

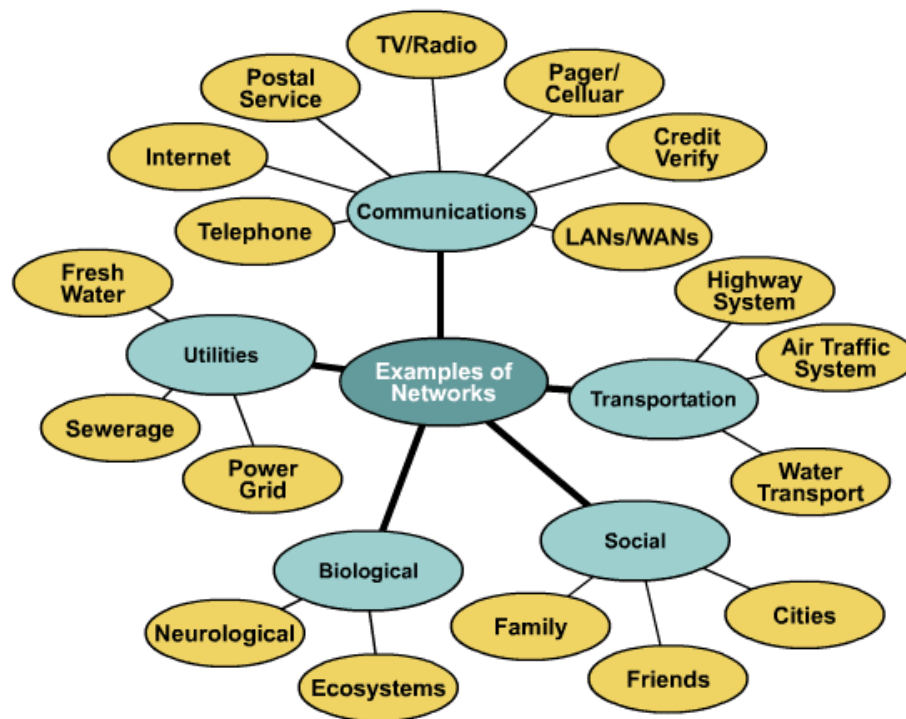


Figure 1: Cluster Diagram

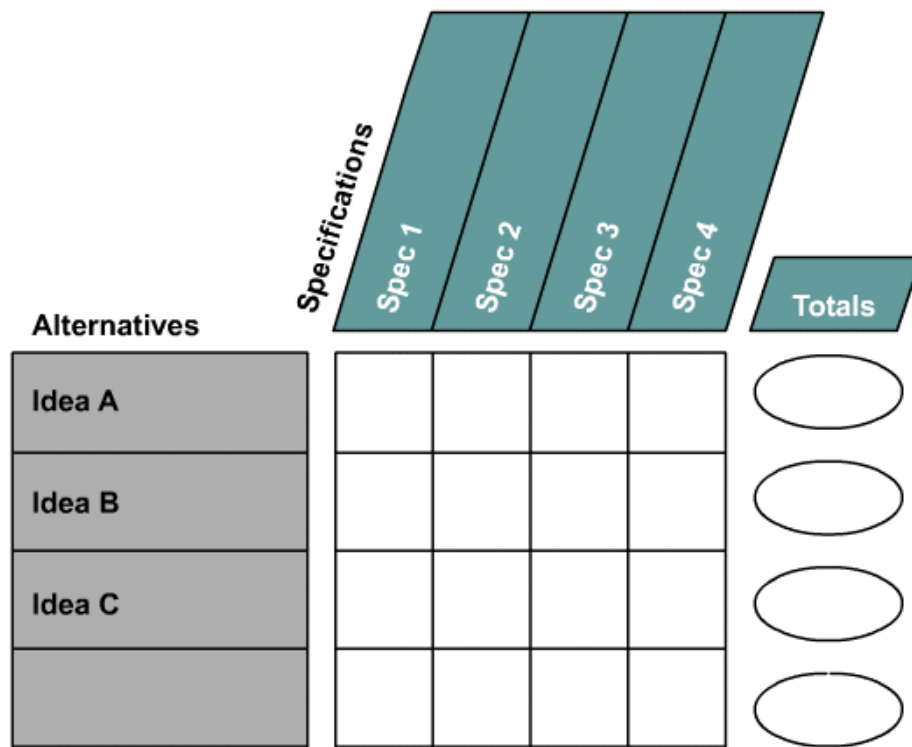


Figure 2: Problem-Solving Matrix

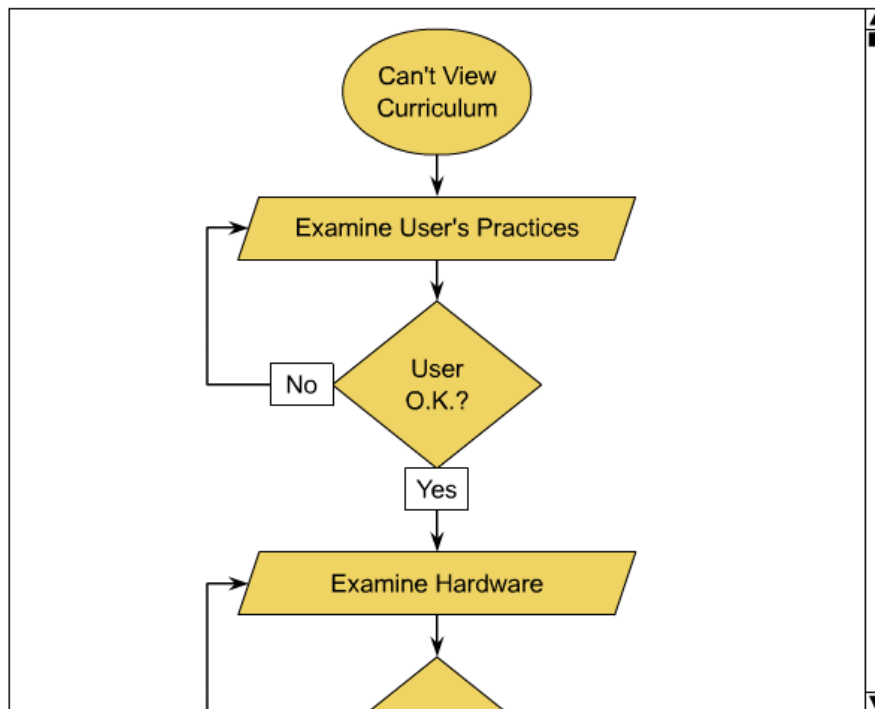


Figure 3: Flowchart

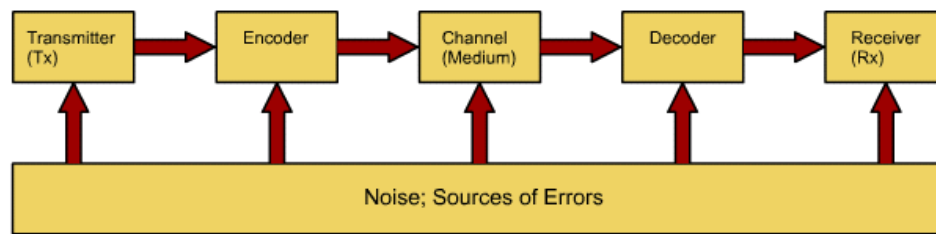


Figure 4: Block Diagrams

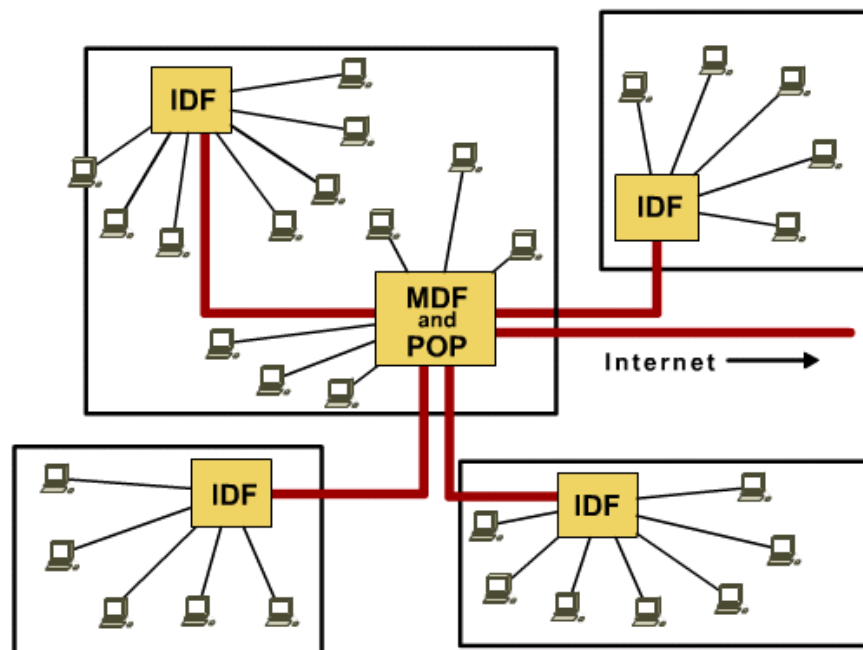


Figure 5: Extended Star Topology in a Multi-Building Campus

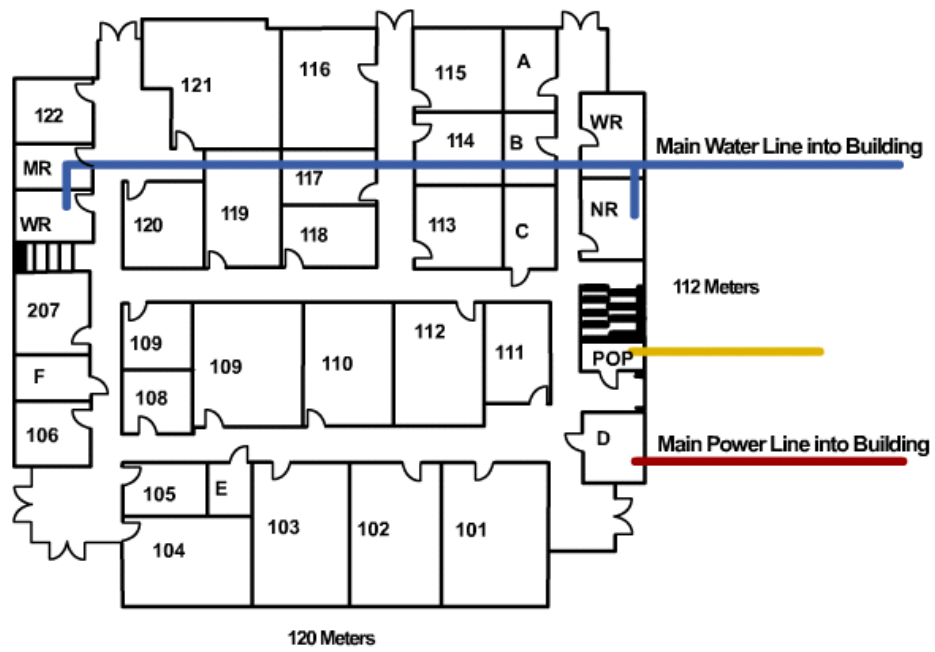


Figure 6: Main Building First Floor

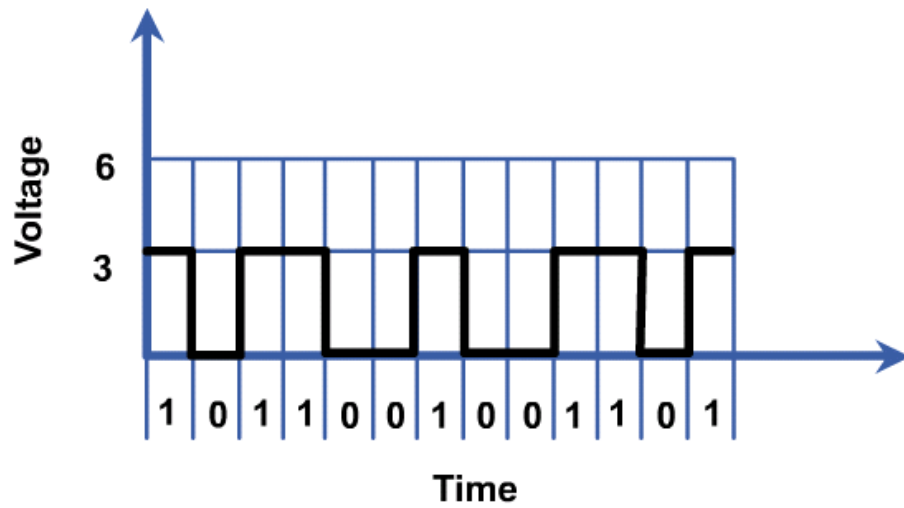


Figure 7: Digital Signal

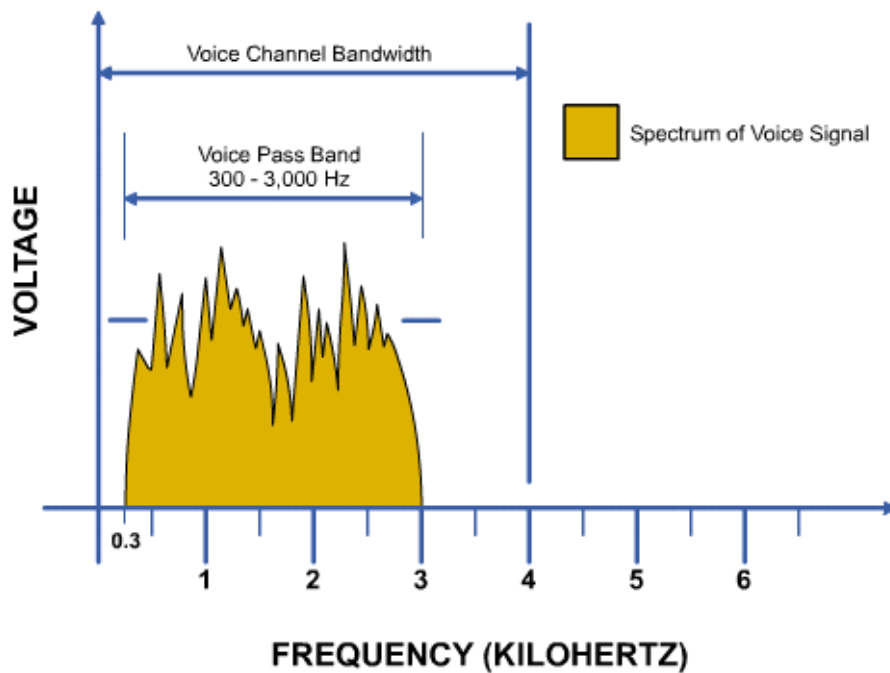


Figure 8: Voltage Versus Frequency Graph (Spectrum Diagram)

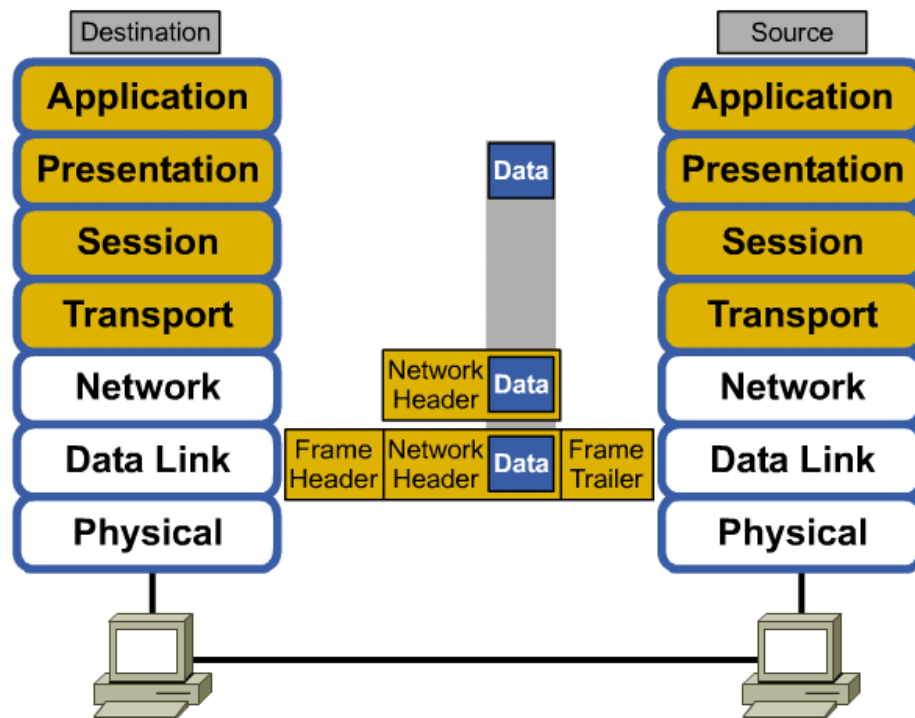
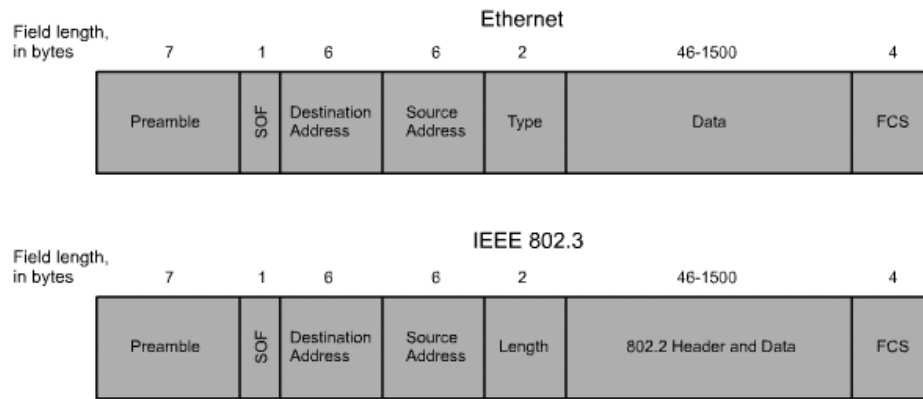


Figure 9: Data Encapsulation



SOF = Start-of-frame Delimiter

FCS = Frame Check Sequence

Figure 10: Ethernet and IEEE 802.3 Frame Format

LANs are designed to:

- ♦ Operate within a limited geographic area.
- ♦ Allow multi-access to high-bandwidth media.
- ♦ Control the network privately under local administration.
- ♦ Provide full-time connectivity to local services.
- ♦ Connect physically adjacent devices.

Using:

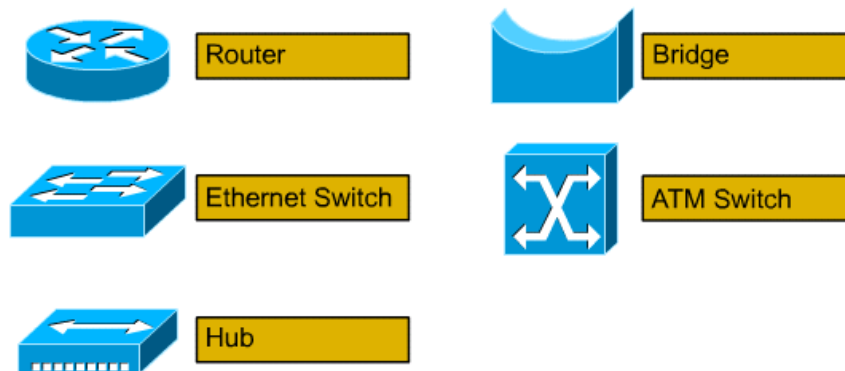


Figure 11: Local Area Networks and Devices

WANs are designed to:

- ♦ Operate over large geographical area.
- ♦ Allow access over serial interfaces operating at lower speeds.
- ♦ Provide full-time and part-time connectivity.
- ♦ Connect devices separated over wide, even global areas.

Using:

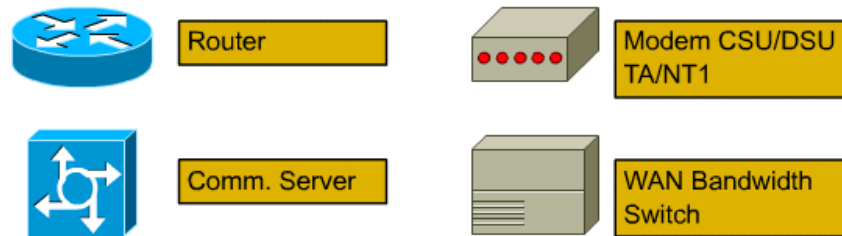


Figure 12: Wide Area Networks and Devices

The use of an advance organizer is another way of determining what prior knowledge a student may have. [1] - [12] This method was first made well known by David Ausubel, a psychologist in the late 1960s. This technique helps students make connections between their current understandings and the information they need to reach a more complete understanding of a learning objective. There are many forms of advance organizers, which include exposition, narrative, or illustration. The graphic organizer allows students to represent their knowledge through shapes, charts, diagrams, and sometimes images. It is a metacognitive tool in visual form. Graphic organizers allow students to arrange a large portion of new information into smaller portion of information. These smaller pieces are easier to learn and when tied together, they will evolve into more comprehensive understandings.

Cluster diagrams are known to be very beneficial in generating and organizing thought. During brainstorming sessions, a prompt is put in the central cluster. The ideas that result from brainstorming are added as more bubbles. These are the wildest possible ideas, with no censorship, as many ideas as possible, and ideas built on those of others. Similar ideas are clustered. This diagram is also used as a concept map, or a way of presenting material to students. It can also be used as way of assessing their understanding of a concept.

Problem-solving matrices are a standard part of design documentation. In their simplest form, a variety of design options, such as network media, network architecture, or protocol, are listed vertically. The specifications against which choices will be rated are listed horizontally. Simplistically, whichever option earns the highest score against the specification rubric is chosen. Realistically, design is a repetitious process and many layers of matrices are typically created with increasingly refined specifications, weighted rubrics, and significant brainstorming and research.

Flowcharts are a standard part of computer programming. Flowcharts and process flow diagrams are generally used to graphically represent various branching processes. Flowcharts are used throughout the curriculum to describe configuration, troubleshooting, and communications processes.

Block diagrams are standard throughout electronics. A few simple symbols, or pictorials, are used along with arrows to indicate the flow of information. Also, simple descriptions of the functions of the various "black box" blocks are shown. Block diagrams represent an intermediate level of detail for electrical systems.

They are not circuit-level schematic diagrams. A block diagram of the following components makes a good accompaniment to flowcharts that explain the processes taking place among the blocks:

- Internal components of a PC
- The internal components of a router
- The devices make up the LAN or a WAN

In networking there are logical topological diagrams and physical topological diagrams. Logical topologies refer to the devices, logical interconnections, and flow of information in a network. Physical topologies refer to the actual devices, logical interconnections, and flow of information in a network. Physical topologies refer to actual devices, ports, interconnections, and physical layout of a network. Both of these diagrams are used extensively.

Electrical engineers refer to voltage versus time graphs of signals as the "time domain". A device called an oscilloscope would measure this type of graph. These graphs summarize many concepts important in networking, particularly in the first semester curriculum. This would include bits, bytes, analog signals, digital signals, noise, attenuation, reflection, collision, AC, DC, RFI, EMI, encoding, and transmission errors.

Web Links

David Ausubel: Advance Organizers Overview

<http://chd.gse.gmu.edu/immersion/knowledgebase/strategies/cognitivism/AdvancedOrganizers.htm>

B.4.8 Setting goals

Students can reach a higher achievement when they have a plan and access the steps necessary to work that plan. The research that has been done on goal setting and its impact on learning is impressive. There are certain truths for students setting personal achievement goals.

Through the process of setting personal achievement goals, students can identify and connect to a greater purpose for reaching their goals. Through reflection, problem-solving, and decision-making, students identify how a goal will bring success. Students define the steps they need to take in order to reach both long-term and short-term goals. They set criteria for each level of achievement and imagine a mental picture of the results they want. With setting personal goals, students create a blueprint for their success. It is important to create a design or an intended course of action. List the small steps as well as the larger milestones. Tap into visual reminders. As progress occurs, students demonstrate dedication to reaching their final goals. Achieving their goal is possible if they are willing to make decisions and modify behavior along the way. Students work their plan, and dedicate their strengths and resources to the goal in spite of diversion, disappointment, and difficulty.

In order to successfully reach their goals, students make connections with other people. They search out people who have the knowledge to advance their understanding and the passion to help keep them motivated and encouraged. Learning requires the assimilation of new understandings into a current set of understandings. Students can be shown how to tap into their personal experiences and knowledge that will enable them to find solutions to their problems.

Finally, there must be some process of evaluation. Students measure their accomplishments at each level of their action plan. Decisions are made continuously to put additional procedures in place that can help them reach the next step toward their definitive goal.

When instructors promote the practice of goal setting in their courses, they provide opportunities to discuss goal-setting skills as they pertain to personal goals. These instructors model time management skills in the classroom as well as monitor student goal setting behaviors. Time is built into the day for students to determine how they are progressing. Sometimes this is done through reflection and journal writing activities. Most importantly, instructors model risk-taking behaviors in the classroom. They encourage their students to not be afraid of trying a new strategy if they think that strategy will help them reach their goals.

B.4.9 Kinesthetic activities

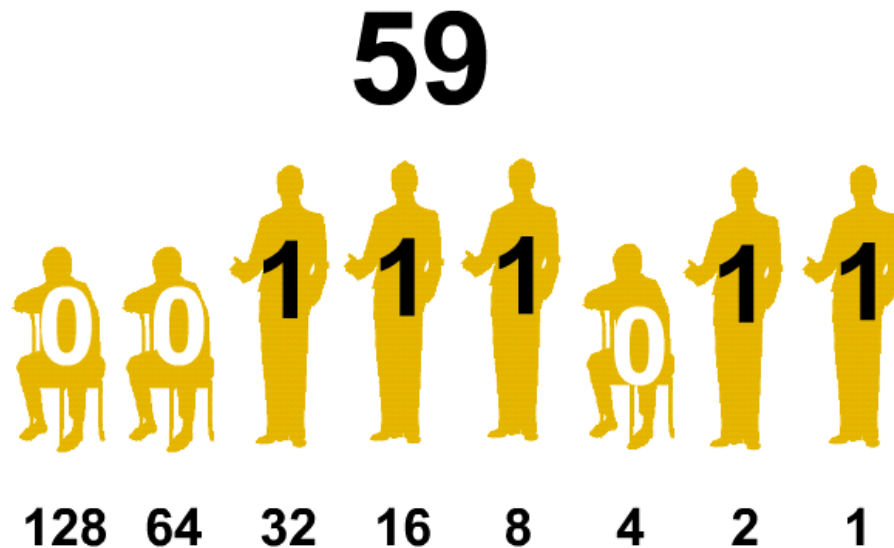


Figure 1: Kinesthetic Activities

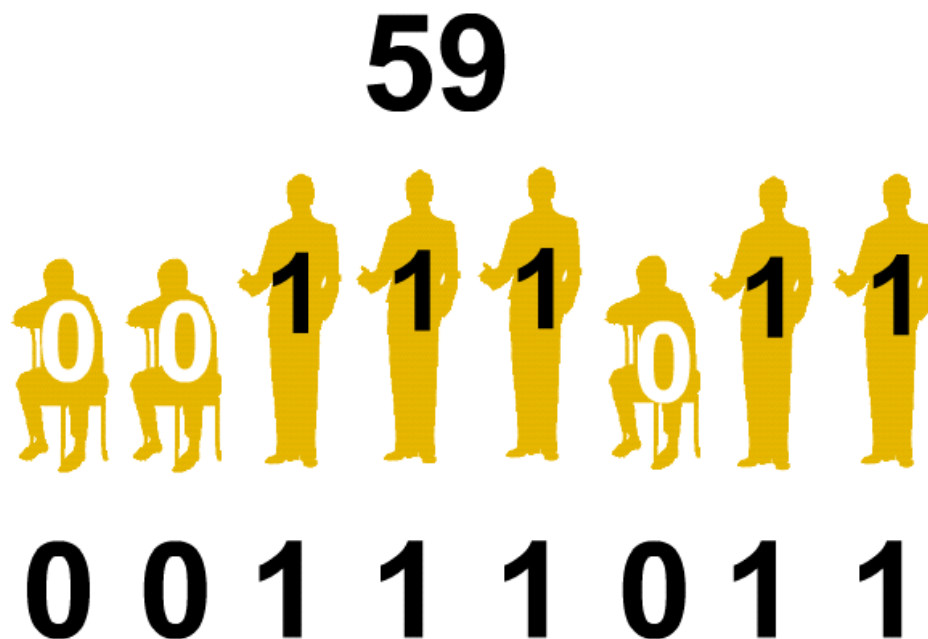


Figure 2: Kinesthetic Activities

A kinesthetic activity refers to the movement of the body to act out or communicate something. In this case, it is the networking process. These exercises might also be known as role-playing activities or skits. They help make complex, normally invisible processes more understandable for students. Kinesthetic activities can be especially helpful when introducing basic IT concepts. Most IT courses require knowledge of binary arithmetic. Figures 1 and 2 show an activity that can be done with eight students. Each student plays the role of a specific place value. For example call out the values, 128, 64, 32, 16, 8, 4, 2, or 1 for 8-bit binary numbers. The instructor calls out a number, between decimal 0 and 255 for 8-bit binary numbers, and each student must decide whether they should be sitting for binary 0 or standing for binary 1. Many IT processes, especially algorithms, may be expressed as kinesthetic activities.

Role-playing is the acting or dramatization of a scenario, story, event, or real life situation. This form of acting can be used to demonstrate a thorough understanding of an event, a discovery, or an interpersonal relationship. Students may create a script for role-playing or ad-lib the actions and dialogue.

Web Links

Kinesthetic Teaching

<http://www.mindsinmotion.org/creative.html>

B.5 Assessment Strategies

B.5.1 Review strategies

Most lessons contain review questions pertaining to content from the previous lesson. Strategies for using the questions can be selected from the following list:

- Individual students answer review questions on their computer.
- Pairs of students discuss and answer review questions on their computer.
- Pairs or small groups of students discuss and answer review questions before each student takes the review.
- The entire class or groups of students discuss review questions and connect to prior understanding through explanation of the questions.
- Small groups each discuss a portion of the questions and demonstrate understanding by explaining to other groups using the jigsaw technique.
- The entire class plays a Jeopardy-like game.
- Student teams or small groups design analogies to explain concepts to other teams of students.

This teaching strategy is similar to a popular television game show called "Jeopardy". The game may be played with pairs, teams of small to large groups, or an entire class. It involves a question and answer session in which one person acting as a host states a fact or the answer. The host leaves out an important name, date, or piece of identifying information. The participant or contestant response to the stated fact is the missing information. This missing information is always returned in the form of a question. The teams, or impartial panels, may create the answers and questions, which are then randomly selected during the activity. If desired, points may be awarded for questions, according to their level of difficulty.

Example:

Fact (question): "This layer is the first layer of the OSI."

Answer: "What is the physical layer?"

Web Links

Learning Through Technology

<http://www.wcer.wisc.edu/nise/cl1/ilt/default.asp>

B.5.2 Journals and reflection

An effective evaluation practice is student journal writing and reflection on academic experience. Students document their individual learning process and highlight their key understandings. A learning log asks students to document their learning steps with special notation around what is clear, what is confusing, and what a student might want to learn more about. From this view of the total student experience, truths surface about how students interact with and process new content. Effective information is revealed so instructors can recognize if students are satisfied with their program and motivated to continue. It is important to remember that journal and reflection writing are self reflective in nature and encourage students to reveal personal thoughts, feelings, and ideas. There may be students who choose not to share this type of information. If instructors decide to practice this type of assessment in their classrooms, there must be clear communication between the instructor and the students as to the purpose of this activity.

The teaching and learning environment is strengthened when instructors and students take time each day for reflection. Metacognition is the concept of persons thinking about their own thoughts. This can be done through written, verbal, kinesthetic, or musical activity. Reflections are a major tool in bringing people to new understandings about their world. By asking essential questions about learning experiences, individuals get better at processing information and they come to be better problem solvers and communicators.

Journals provide a space for inner thought and reflection on experiences gained during the teaching and learning process. For classrooms that infuse journal writing into curriculum and class time, there is usually a period of time set aside during the day for this process. During this time, the teacher and student might reflect on completed tasks or make predictions about future experiences. Thoughts and ideas can be written down in a dedicated, personal paper space or in a word processor file. These thoughts can take the form of words, sentences, illustrations, maps, charts, magazine pictures, and newspapers among a host of other media. Through fundamental and underlying questioning, journaling can take the form of guided writing or free style writing. Through this type of reflection, the teacher and student can track their evolving understanding of issues and themes.

For Academy courses, instructors may want to have students to keep a technical, or engineering journal, in which to record details involving all aspects of their network design and installation experiences. While it may not seem important to them at first, it will develop a good habit and will eventually become more important as they increase their networking experiences. Typically, the journal is a paperbound composition book in which pages are dated and added, but never subtracted. The entries would include such things as daily reflections, troubleshooting, details, procedures and observations, equipment logs, hardware and software notes, and router configurations.

Student reflection is an important element of instruction that takes only a brief amount of time per lesson. The process helps students analyze their own learning over time and become more responsible for their learning. During reflection, the students think back upon some aspect of the lesson and write a reaction to that aspect in the Study Guide. This internalization of learning helps the students make sense of the learning process. It also links prior learning to present and future learning. The reflection process helps students to analyze and synthesize new understandings. Then through the cognitive processes of assimilation and accommodation, they move learning from short term to long-term memory. After each lesson, reflection is done in one or more of the following categories:

- Content
- Product
- Process
- Progress

Throughout the year, it is beneficial to have students look back over their reflections and acknowledge the growth in their understanding. Prior to any given reporting period, it would be insightful to have students write a brief paper explaining their growth in knowledge as well as skills during the preceding weeks.

The following provides some examples of reflection and journal writing for Academy courses:

Elements:

- Key ideas from class presentations
- Discussions
- Lesson content
- Activities in terms of content

- Process
- Product
- Progress
- Personal analysis that shows a connection with the content purpose
- Questions or statements that indicate a need for further clarification or inquiry
- Attention to the process involved in accomplishing an important task
- Product specific application of learned material to other content or subjects
- Demonstrating the connection between concept or content
- Thoughtfulness as demonstrated by goals for improvement
- Other actions that demonstrate self-learning

Content:

- From this assignment I learned. . .
- What I needed to know better before I started was. . .
- What I need to learn more about is . . .
- This content helps me understand the connection. . .
- The most important concepts I learned in this lesson were. . .

Product:

- This product demonstrates my skills in the following ways. . .
- This product would have been better if. . .
- A better way to have demonstrated my skills might have been. . .

Process:

- Strategies that worked well in doing this performance task/product were. . .
- Strategies that did not work well for me in doing this performance task/product were. . .
- Working in a small group was _____ because. . .
- The teacher helped or hindered my learning by. . .

Progress:

- By doing this unit or lesson I now know that I. . .
- I am more able to. . .
- I still need to work on. . .
- Some goals for further learning include. . .
- I can apply what I have learned in. . .

Web Links

Student Reflection Questions

<http://pblmm.k12.ca.us/PBLGuide/PlanAssess/StReflectionQuestions.html>

B.5.3 Rubrics

FWD Instructor Grading Rubric - Final Project

Group Members:

Site Name: _____

Site URL: _____

The final project combines several key concepts from the curriculum and the lab exercises completed in GoLive, Photoshop, LiveMotion, and Illustrator.

The student site must accommodate the following:

- A minimum of 10 pages including a home page w/ mission statement
- Interactivity (guest book, feedback form, survey)

Figure 1: Grading Rubric Sample

Another best practice is the use of rubrics as a form of assessment. A rubric allows criteria to be established for outcomes acquired during individual or group projects. Levels of success and quality are identified at different levels of a predetermined scale. Quantitative data can be associated with each level of performance. Basically the rubric evaluates the learning behavior that can be observed. The rubric assesses all curriculum content connections associated with a project. It also assesses other components such as design, evidence of researching skills, organization of thought, cooperative skills, and communication of emerging knowledge. The rubric has two primary functions for teaching and learning. It communicates the expectation and gives students a target of achievement to work toward. One of the most important benefits of rubric assessment is the control it puts in the hands of students. Students can be allowed to create their own rubrics based upon established standards and performance objectives. Assessment is ongoing with self-monitoring and self-evaluation. With access to a direction and the freedom to choose their path of learning, many students are empowered to very high achievement.

For Academy courses, the rubric creates specific expectation criteria for the final performance of a lab or activity. For the demonstration of each task, there is a specific set of performance levels for all objectives, content, and skills. The rubric contains a criterion that defines the key elements indicating learning proficiency. Many rubrics are based on a four-point scale, with the exemplar level being four points. Each of the points on the scale has specific criteria that describe the characteristics of a performance. Before beginning an assessment of student interactions, classroom work, or any performance lab or activity, students should be made aware of their expectations. This will help them begin the process of self-assessment as they progress through the individual tasks that are reflected in the rubric. Students and teachers developing rubrics together can help the students organize and prepare for learning by knowing in advance their assessment expectations. It also allows them to take part in developing the grading scale for their performance labs or activities.

Web Links

RUBISTAR

<http://rubistar.4teachers.org/>

Rubrics and Assessments

<http://home.socal.rr.com/exworthy/rubric.htm>**link does not work and no suggestion...***

B.5.4 Portfolio

The portfolio is an example of authentic assessment. As students complete major presentations or projects, they are saved as exemplars within the networking field. For many jobs, a portfolio of accomplishments must be presented during the hiring process. Portfolios show the growth of students over time and include their reflections on different periods of learning. Academy students might keep a portfolio of their experience in building a network and examples of configurations they created for different scenarios. Also, community projects represent an authoritative example of accomplishment.

A portfolio is a collection, either in paper or online form that shows the best work done by the student during a semester. As with any educational initiative, it is subject to ongoing revision and improvement. Many secondary school districts are encouraging portfolio-based assessments. The Networking Academy program is well suited for this type of assessment. Students maintain their portfolios, which eventually will include all of their best work throughout all semesters of a particular curriculum. This portfolio can contribute to graduation criteria encouraged by the local academy. It can also serve as an impressive display for potential employers.

Web Links

Guidelines for Portfolio Assessment in Teaching English

<http://www.etni.org.il/ministry/portfolio/default.html>

B.5.5 Oral exams

Date/Time/Place:						
Group#	Time (25 min slots)	Member #1	Member #1	Member #1	Member #1	Member #1
1	3:00-3:25					
2	3:30-3:55					
3	4:00-4:25					
4	4:30-4:55					
5	5:00-5:25					
6	5:30-5:55					

NOTE: ANY MEMBER OF ANY GROUP MAY BE ASKED ANY OF THESE QUESTIONS!

Learning Goals

- Encouraging students' skills in quick recall of facts and concepts and "thinking on their feet."
- Assessing student understanding in ways deeper than multiple-choice questions.
- Learning professional standards for answering questions and articulating concepts orally under time pressure.
- Engaging students' multiple intelligences and providing a prompt for group-based studying and learning.

Figure 1: Oral Exams

#	Time Limit (minutes)	Prompt (exact wording given to student)	Point Value	Sample Responses (to earn that point value)
1	5	<p>Give the student a situation (a school to be wired or a project they completed during the semester)</p> <p>Choose media, justifying your choice with a matrix</p> <p>Draw a simple physical topology, locationing POP, MDF, IDF, MCC, ICC, HCC backbone. Justify all choices of locations.</p> <p>Draw a simple flowchart of what you would do to design, install, and test the cabling you've intalled</p>	4	<p>+1 for comparison of media choices and proper use of matrix</p> <p>+2 for reasonable locations and justifications</p> <p>+1 for a chart which include planning porcesses, installing jacks, stringing cable, and using test equipment</p>

Figure 2: Oral Exams

Well-planned oral examinations can be powerful learning experiences for students. The usual intimidation factor that is felt by some students can be minimized with careful preparation. Traditionally, the models for such exams are centered on job interviews and graduate school oral exams. [1] [2] One method that works well, particularly with groups of diverse learners, is to give teams of students the exam questions, answers, and rubrics in advance of the scheduled exam session. Establish a pre-scheduled exam time. This might be after school unless there are block periods. Then, each individual member of the team enters the room alone and is asked one of the questions by the board. While studying and assessment are group-based activities, each individual must answer one of the questions without knowing in advance which question might be asked. This method of oral testing usually motivates the students to study very hard. Examples are found in Semester 2 Lesson Plans. Instructors are encouraged to develop their own technique for conducting oral examinations and to consider using them especially when testing for "Benchmark Understandings".

B.5.6 Lab exams

Lab Exam/Skills Exam Examples from Academy Curriculum

Curriculum	Vendor	Skills Tested
CCNA	Cisco	
CCNP	Cisco	
IT Essentials	HP	
Fundamentals of Voice and Data Cabling	Panduit	
Unix	Sun	
Java	Sun	
Web Design	Adobe	

Figure 1: Lab Exams

Lab exams are also known as "skills exams". These exams provide students an opportunity to demonstrate their understanding of configuring cables and routers. Students come to the lab where they assemble a network using cables and routers. Their performance task is to connect cables and routers so every router can successfully talk to one another. The number of routers to connect will vary according to equipment access. This process is one that distinguishes Cisco from all other programs. When students graduate from an Academy, they have been tested for their hands-on expertise with equipment and pass an exam stating to that effect. This practice supports authentic assessment and brings a higher credibility to students in the job market.

Lab exams include all of the following:

- Practical exams
- Performance exams
- Demonstration labs
- Skills-based and performance assessments
- Authentic assessment
- Mastery learning

- Formative and summative exams

Cisco recommends simple pass/fail grading, with opportunities for retaking the skills exam if necessary.

Web Links

Certification Magazine

http://www.certmag.com/issues/aug01/feature_long.cfm

CCIE

<http://www.cisco.com/warp/public/625/ccie/>

B.5.7 Six Lenses

Six Lenses
<ul style="list-style-type: none"> ▪ Equity ▪ Curriculum ▪ Teaching ▪ Learning ▪ Assessment ▪ Technology

Figure 1: Six Lenses

During any learning endeavor, certain lenses are indispensable for assuring a high quality experience for the students. The following are six different perspectives that support teaching the Academy courses:

- Equity
- Curriculum
- Teaching
- Learning
- Assessment
- Technology

It is important for these questions to be asked in reference to all Academy curriculums. The following is a sample. UNIX is used as an example for the purpose of this content.

Example:

- **Equity** – Do all Academy students have "adequate" access to learning UNIX?
- **Curriculum** – Does the online curriculum and skills-based lab provide optimum opportunity for students to learn UNIX?
- **Teaching** – Do all Academy students have access to instructors who use Instructional Best Practices to teach UNIX?
- **Learning** – Do students have adequate resources to construct their own iteratively corrected understandings of UNIX?

- **Assessment** – Do all students have access to online and skills-based formative and summative assessments?
- **Technology** – What technologies enable the effective teaching of UNIX?

As instructors work through this Orientation course, Cisco encourages them to keep revisiting these essential questions. In this section of the course, Cisco has attempted to present some useful content, tools, and perspectives. Ultimately, what is best for students is the teaching by the instructor.